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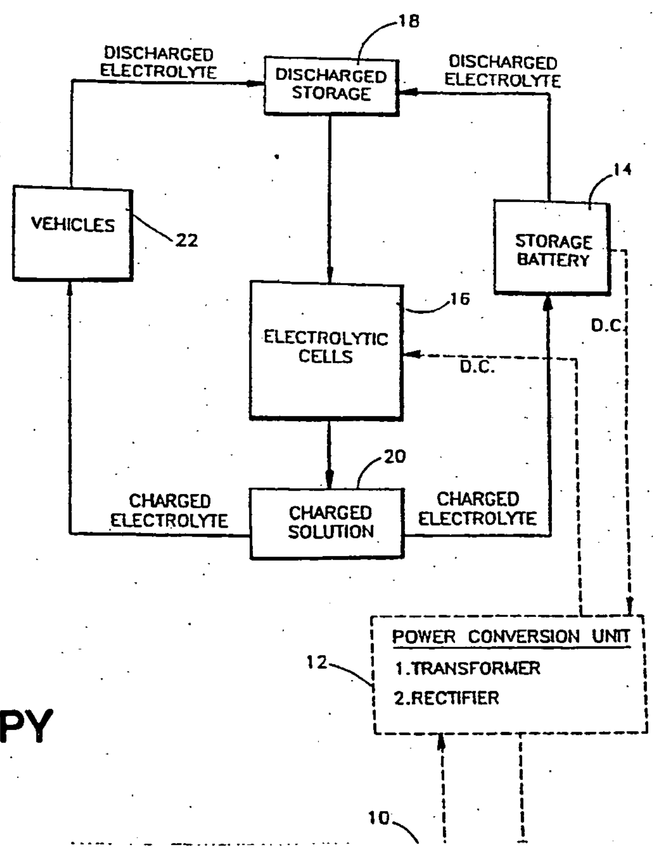
(54) Title: RECHARGEABLE ELECTRICAL POWER STORAGE UNIT APPARATUS FOR USE IN AN ELECTRICAL TRANSPORT SYSTEM

(57) Abstract

Rechargeable electrical power storage apparatus including an electrical power storage unit (14) having one or more rechargeable electrical cells containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state; apparatus for converting the discharged storage medium from a relatively less flowable form to a relatively more flowable form; and apparatus for removing the discharged storage medium in said relatively more flowable form from each cell.



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RECHARGEABLE ELECTRICAL POWER STORAGE UNIT APPARATUS FOR USE IN AN ELECTRICAL TRANSPORT SYSTEM

FIELD OF THE INVENTION

The present invention relates to electrical energy systems generally and more particularly to electrical energy systems incorporating electric vehicles.

BACKGROUND OF THE INVENTION

Over the years, various proposals have been made for electric powered vehicles. To date, for a number of reasons, electric vehicle systems have yet to become commercial for urban and highway applications.

There have been proposals to employ zinc/air batteries for urban vehicle propulsion. An example is the following publication:

Improved slurry zinc/air systems as batteries for urban vehicle propulsion, by P.C. Foller, Journal of Applied Electrochemistry 16 (1986), 527 - 543.

Metal/air battery structures are described in the following publications:

U.S. Patent 4,842,963, entitled Zinc Electrode and Rechargeable Zinc-Air Battery;

U.S. Patent 4,147,839, entitled Electrochemical Cell with Stirred Slurry;

U.S. Patent 4,908,281, entitled Metal/air Battery with Recirculating Electrolyte;

U.S. Patent 3,847,671, entitled Hydraulically-Refuelable Metal-Gas Depolarized Battery System;

U.S. Patent 4,925,744, entitled Primary Aluminum-Air Battery;

U.S. Patent 3,716,413, entitled Rechargeable Electrochemical Power Supply;

U.S. Patent 4,925,744, entitled Primary Aluminum-Air Battery;

Electrical energy storage systems are described in the following publications:

U.S. Patent 4,843,251 entitled Energy Storage and Supply Recirculating Electrolyte;

Energy on Call by John A. Casazza et al, IEEE Spectrum June, 1976, pp 44 - 47.

U.S. Patent 4,275,310, entitled Peak Power Generation;

U.S. Patent 4,124,805, entitled Pollution-Free Power Generating and Peak Power Load Shaving System;

U.S. Patent 4,797,566, entitled Energy Storing Apparatus.

The teachings of the foregoing publications are hereby incorporated herein by reference.

SUMMARY OF THE INVENTION

The present invention seeks to provide improved, rechargeable, electrical power storage apparatus including apparatus for efficiently recharging the storage apparatus.

A further aim of the present invention is to provide an electrically powered vehicle utilizing the improved rechargeable power storage apparatus of the invention.

There is provided, therefore, in accordance with an embodiment of the invention, rechargeable electrical power storage apparatus including an electrical power storage unit having one or more rechargeable electrical cells containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state; apparatus for converting the discharged storage medium from a relatively less flowable form to a relatively more flowable form; and apparatus for removing the discharged storage medium in its relatively more flowable form from each cell.

There is also provided, according to an alternative embodiment of the invention, an electrical transport system including an electrically powered vehicle having vehicle drive apparatus; rechargeable electrical power storage apparatus electrically coupled to the vehicle drive apparatus, and including one or more rechargeable electrical cells containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state; apparatus for converting the discharged storage medium into a relatively more flowable form; and apparatus for removing the discharged

storage medium in its relatively more flowable form from each cell.

According to yet a further embodiment of the invention, there is provided an electrical energy system including an electric utility having electricity generation apparatus and distribution lines; a plurality of electric vehicles, each having vehicle drive apparatus; a rechargeable electrical power storage unit electrically coupled to the vehicle drive apparatus, and including one or more rechargeable electrical cells containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state; apparatus for converting the discharged storage medium into a relatively more flowable form; apparatus for removing the discharged storage medium in its relatively more flowable form from each cell; and

electric power storage apparatus receiving electrical power from the electric utility and supplying electrical power to each rechargeable electrical power storage unit and to the electric utility when required.

Additionally in accordance with an embodiment of the invention, the apparatus for converting includes apparatus for directing jets of a liquid at the discharged storage medium contained in each cell, thereby causing disintegration of the discharged storage medium into particles, thereby resulting in a particle/liquid suspension.

Further in accordance with an embodiment of the invention, the apparatus for removing includes apparatus for pumping the particle/liquid suspension from each cell.

Additionally in accordance with an embodiment of the invention, the apparatus for pumping is operatively associated with a supply of charged power storage medium so as to supply a predetermined volume of the charged power storage medium to each cell.

Further in accordance with an embodiment of the invention, each cell is a metal/air cell, the power storage medium is a metal/air slurry, and the electrical power storage unit also includes an air conduit system for permitting air flow in operative association with each cell.

Additionally in accordance with an embodiment of the invention, there is also provided apparatus for selectably circulating an inert, non-reactive gas, e.g. nitrogen, around each cell so as to prevent the supply of air thereto, thereby preventing electrochemical activity of the electrical power storage unit.

According to an additional embodiment of the invention, there is provided a method of recharging a rechargeable electrical power storage unit having one or more electrical power storage cells, each containing a rechargeable electrical power storage medium which is relatively more flowable when in a charged state and relatively less flowable when in a discharged state, the method including the steps of converting the discharged storage medium into a relatively more flowable form; removing the discharged storage medium in its relatively more flowable form from each cell; and supplying charged storage medium to each cell.

Additionally in accordance with an embodiment of the invention, the step of converting includes the step of directing jets of a liquid at the discharged storage medium contained in each cell so as to cause disintegration of the discharged storage medium into particles, thereby resulting in a particle/liquid suspension.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1 is a block diagram illustration of an electrical energy system constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 2 is a more detailed block diagram of the system of Fig. 1;

Fig. 3 is a schematic illustration of an electric vehicle battery recharging subsystem forming part of the system of Figs. 1 and 2;

Fig. 4 is a pictorial block diagram of an electrolyte regeneration facility forming part of the system of Figs. 1 and 2;

Fig. 5 is a flow-chart of the operation of the regeneration facility of Fig. 4;

Figs. 6 and 7 are general schematic illustrations of two types of electric vehicle useful in the system of Figs. 1 and 2;

Figs. 8A, 8B and 8C are respective side, top and end view schematic illustrations of the vehicle of Fig. 7, illustrating the general location of major operating systems therein;

Fig. 9 is a partially cut away illustration of the installation of a zinc-air battery in a vehicle of the type illustrated in Fig. 6;

Figs. 10 and 11 are illustrations of two variations of a zinc-air battery suitable for use in electric vehicles;

Fig. 12 is a schematic illustration of a thermal management subsystem useful in the vehicles of Figs. 6 and 7;

Fig. 13 is a pictorial illustration of a multi-cell metering pump assembly useful in the system of Figs. 1 and 2;

Fig. 14 is an exploded view illustration of an zinc-air battery cell useful in the present invention;

Fig. 15 is a partial sectional illustration of the assembly of the battery cell of Fig. 14;

Fig. 16 is a pictorial illustration of the battery cell of Fig. 14;

Fig. 17 is an exploded view illustration of assembly of the battery cell of Fig. 14;

Fig. 18 is a pictorial illustration of a zinc air utility storage battery useful in the system of Figs. 1 and 2;

Fig. 19 is a schematic illustration of the connection of the battery of Fig. 18 in its operating environment;

Fig. 20 is a block diagram illustrating the principal functional components of the battery of Fig. 19;

Figs. 21 and 22 are flow chart illustrations of power station utility battery charging and discharging functions respectively;

Fig. 23 is a cross-sectional view of a zinc-air battery cell constructed according to an alternative embodiment of the invention;

Fig. 24 is a schematic illustration of the current collector employed in the battery cell of Fig. 23;

Figs. 25A - 25D are schematic illustrations of stages in the replacement of discharged slurry with charged slurry;

* Fig. 26 is a flow chart illustration of the slurry replacement process depicted pictorially in Figs. 25A - 25D;

Fig. 27 is sectional illustration depicting the cleaning of discharged slurry from an array of central current collectors, taken in the direction of line 27-27 in Fig. 25C;

Figs. 28A and 28B are respective side and cut-away plan view illustrations of a typical electric vehicle employing rechargeable, electrical power storage apparatus constructed and operative according to a further embodiment of the invention;

Fig. 29 is an isometric view of a portion of the power storage apparatus employed in the vehicle of Figs. 28A and 28B;

Fig. 30 is an enlarged isometric view of the slurry/liquid main conduits depicted in Fig. 29;

Fig. 31 is a schematic cut-away view of a single zinc/air cell of the power storage apparatus of Fig. 29; and

Fig. 32 is a sectional illustration of a portion of the cell of Fig. 31 taken along line 32-32 therein.

DETAILED DESCRIPTION OF THE INVENTION

Reference is now made to Fig. 1, which illustrates in generalized block diagram form an electrical system constructed and operative in accordance with a preferred embodiment of the present invention and including an electrical utility having electricity generation apparatus and distribution lines, a plurality of electric vehicles and electric power storage apparatus receiving electrical power from the electric utility and supplying electrical power to the plurality of electric vehicles and to the electric utility when required.

Illustrated in Fig. 1 is an AC transmission line 10 which is arranged for power transfer via a power conversion unit 12 with a storage battery bank 14 and with a bank of electrolytic cells 16. The electrolytic cells 16 are operative to electrically charge an energy storage slurry, such as a mixture of zinc granules and alkaline potassium hydroxide solution, thereby storing energy therein.

In the illustrated embodiment, discharged slurry is stored in a discharged slurry storage facility 18 and supplied to electrolytic cells 16 via suitable pumps (not shown). The charged slurry is received in a facility 20 and then stored in storage battery 14 or supplied to electric vehicles 22.

Discharged slurry is received at facility 18 from the electric vehicles 22 and from storage battery 14. The storage battery 14 provides, when necessary or economical, electrical power to transmission line 10 via conversion unit 12.

It will be appreciated by persons skilled in the art that the present invention, through the synergistic combination of two disparate activities, utility energy storage and electric vehicle operation, each of which is presently uneconomical, provides economical electrical utility off-peak power storage, surge protection, on-peak and super-peak demand power supply, spinning reserve and electric vehicle system.

Reference is now made to Fig. 2, which illustrates the system of Fig. 1 in greater detail. As shown in Fig. 2, the AC utility transmission line, here indicated by reference numeral 30, is coupled via a transformer 32 to a power line conditioner 34 which includes high capacity AC to DC and DC to AC converters. Reactive and other line control apparatus 36, such as peak switching in detectors may be associated with the power line conditioner 34.

A DC output of conditioner 34 may be supplied via a slurry reconditioning control circuitry 38 to a slurry reconditioning facility 40. The DC output of conditioner 34 may also be supplied via a charge control unit 42 to a bank of lead acid batteries 44.

Slurry reconditioning facility 40 is operative to provide charged slurry, via slurry pumping apparatus 46 to an electric vehicle refueling station 48, for supply to electric vehicles. Facility 40 is also operative to supply charged slurry via slurry pumping apparatus 46 to a zinc air battery 50. Charged slurry from facility 40 may also be stored in a charged slurry storage tank 52.

Discharged slurry removed from electric vehicles is supplied from electric vehicle refueling station 48 to a discharged slurry storage tank 54 and is supplied at appropriate

times to facility 40 by slurry pumping apparatus 46. Normally recharging of slurry is carried out by facility 40 during off-peak times for utility supplied electricity.

Electrical power may be drawn from battery 50 when needed, and supplied via discharge control circuitry 56, power line conditioner 34 and transformer 32 to the utility via power line 30. Normally power is supplied to the utility from battery 50 at times of peak power consumption.

Electrical power may be drawn from battery 44 when needed, and supplied via discharge control circuitry 58, power line conditioner 34 and transformer 32 to the utility via power line 30. Normally power transfers between battery 44 and utility power line 30 take place in order to balance the impedance of the power line 30, to absorb short term peaks and shortfalls, typically having a time constant of less than one-half hour.

Reference is now made to Fig. 3, which is a pictorial illustration of an electric vehicle refueling station, such as station 48 (Fig. 2). As shown in Fig. 3, the refueling station includes a plurality of drain units 60 which are operative to remove discharged slurry from electric vehicles 62. The discharged slurry is supplied to discharged slurry storage tank 54 (Fig. 2).

Automatic moving platforms 64 are preferably provided for moving the electric vehicles 62 from the drain units 60 to charged slurry supply units 66, which supply charged slurry from charged slurry storage tank 52 to the electric vehicles 62.

Reference is now made to Fig. 4, which illustrates electrolytic reprocessing subsystem, which is indicated generally by reference numeral 16 in Fig. 1. Discharged slurry, here of the composition: unreacted zinc granules, zinc oxide and alkaline potassium hydroxide solution, stored in tanks 74, is supplied to a bank of electrolytic baths 78, such as modified alkaline zinc plating baths with scrapers for periodically removing zinc deposits thereon. Baths 78 receive an electrical input from power conversion unit 12 (Fig. 1).

Freshly generated zinc mixed with alkaline potassium hydroxide solution is pumped from electrolytic baths 78 to a zinc treatment facility 80, such as a classifier for particle sizing, which provides a purified zinc output to a storage tank

82. KOH is received from electrolytic baths 78 and is supplied to a holding tank 84. The contents of tanks 82 and 84 are supplied to a formulation tank 86 in which they are combined to provide a recharged slurry. The recharged slurry is stored in a storage tank 88.

Reference is now made to Fig. 5, which describes the operation of the apparatus of Fig. 4. It is see that the discharged electrolyte slurry containing Zn, ZnO, Zno2=ö and KOH has its concentration adjusted by the addition of KOH. Subsequently, the discharged electrolyte having a predetermined concentration undergoes separation and reduction, the KOH being removed to a KOH storage tank such as tank 86 (Fig. 4) and the solids being supplied to a zinc storage facility, such as tank 82 (Fig. 4). The zinc is supplied to a reformulation facility such as tank 84 (Fig. 4) in which KOH and other additives are added to the zinc to provide a regenerated slurry which is stored as in tank 88 (Fig. 4).

Reference is now made to Fig. 6, which illustrates a typical electric car, including a zinc air battery 100. As seen with greater particularity in Fig. 9, the zinc-air battery 100 is typically located centrally along the longitudinal axis of the car and is mounted on frame rails 102. Provision is made for distilled water dropping tubes 104 and a scrubbed air flow channel 106 within an air tight enclosure 108, which surrounds the battery cells 110. Enclosure 108 is typically covered by thermal and acoustic insulation 112. The structure of the battery and its function may be based on known principles and designs which are set forth, inter alia in the references cited in the Background of the Invention section hereinabove, the disclosures of which are hereby incorporated by reference.

Reference is now made to Figs. 7, 8A, 8B and 8C which illustrate the general configuration of an electric driven van useful in the present invention. As seen in Fig. 7, the van is provided with two zinc-air battery banks 120 and 122 on opposite sides of the body. An auxiliary lead-acid battery 124 is preferably provided in addition. A power swi ching system 126 governs the supply of power to and from the various batteries.

Figs. 8A, 8B and 8C also illustrate preferred locations of a 12 volt vehicle utility battery 128, a traction

motor and drive 130, a cabin heater 132, and a DMS (Driving Management System) 134.

Reference is now made to Fig. 10, which illustrates one embodiment of zinc-air battery suitable for powering an electric vehicle. The battery includes a multiplicity of cells 140 which are arranged in association with a slurry filling port 142, a slurry drain port 144 as well as coolant inlets and outlets 146 and 148 respectively and treated air inlets and outlets 150 and 152 respectively.

An alternative battery configuration is illustrated in Fig. 11 and includes a multiplicity of cells 160 which are arranged in association with a slurry filling port 162, a slurry drain port 164 as well as coolant inlets and outlets 166 and 168 respectively and treated air inlets and outlets 170 and 172 respectively.

Fig. 12 illustrates a thermal management arrangement for an electric vehicle battery of the type illustrated in Figs. 10 and 11. The battery is indicated by reference numeral 180. A coolant passes therethrough as indicated in solid lines. Temperature sensors 182 and 184 are located respectively at the coolant inlets and outlets to the battery 180.

Heated coolant from the battery 180 is supplied via a circulating pump assembly 186 via a cabin heating system 188, for heating of the vehicle cabin as necessary and via a radiator assembly 190 for cooling of the coolant.

Operation of the entire system is governed by a suitable battery thermal control units, which receives inputs from temperature sensors 182 and 184 as well as from a temperature sensor 196 associated with the cabin heating system 188 and provides control outputs to cabin heat system fan motor 198 and radiator fan motor 200 as well as control inputs to the fuel heater 194, pump 186, and a cabin heating system input valve 202 and a radiator input valve 204.

Reference is now made to Fig. 13, which illustrates a typical arrangement for metering the supply and drain of slurry in a battery unit. The apparatus shown in Fig. 13 includes a recharged slurry tank 206, which outputs into a manifold 212 having a plurality of outlets 214, each of which is supplied with a non-return valve 216 and communicates with a battery cell

218. Draining of slurry from the battery cells 218 takes place via an outlet manifold arrangement 220 including non-return valves 222 for each cell. A common drain conduit 224 is provided for removal of discharged slurry.

Reference is now made to Figs. 14, 15, 16 and 17 which describe the construction of a modular zinc air battery according to the present invention. It is seen that each cell includes a plastic frame 250, a current collector 252, typically formed of nickel mesh, an air electrode 254, typically formed of a wet-proofed, catalyzed carbon layer formed on the nickel mesh, a separator 256, typically formed of nonwoven porous nylon, a plastic frame 258, a central current collector 260, typically formed of nickel plated copper, a plastic frame 262, a separator 264, typically formed of nonwoven porous nylon, an air electrode 266, typically formed of a wet-proofed, catalyzed carbon layer bonded to nickel mesh, a current collector 268 typically formed of nickel mesh, and a plastic frame 270, typically formed of polypropylene.

Fig. 15 illustrates a section of an individual cell taken through its narrowest dimension. Fig. 16 illustrates such a cell in a partially cut away illustration, and Fig. 17 shows a cell assembly in exploded view.

Reference is now made to Figs. 18, 19 and 20 which illustrate the general configuration of a zinc-air utility storage battery. It is noted that the battery comprises a multiplicity of cells 300, each containing, inter alia an air electrode 301 and a current collector 303, connected in series. Air is supplied from the outside atmosphere by a blower 302 via a CO_2 scrubber 304.

Slurry is pumped to and from the cells 300 by pumps 306. Thermal management apparatus 308 is provided as is a water humidifier 310. Apparatus 308 is operative to ensure optimum operating temperatures for the battery irrespective of the local ambient temperature and deals with parasitic heat generated by the battery during discharge. Humidifier 310 is operative to control the humidity of the incoming air to the battery and prevents slurry dry-out.

Reference is now made to Figs. 21 and 22 which illustrate the function of the utility battery during respective

charging and discharging operations. During charging, AC line power is supplied via a transformer 320, rectifier 322 and control unit 324 to the battery.

During discharge, as illustrated in Fig. 22, power from the battery 300 is supplied via control unit 324, AC converting unit 336 and transformer 320 to the AC line.

Reference is now made to Figs. 23 - 26, in which there are illustrated a battery cell construction and apparatus for replacing discharged slurry therein with charged slurry, in accordance with a preferred embodiment of the invention. It will be appreciated by persons skilled in the art, that discharged slurry has a much greater viscosity than charged slurry, and that it may, therefore, be useful to provide a direct mechanical method of removing discharged slurry from a battery cell, wherein the effectiveness of the method is not significantly influenced by the viscosity of the slurry.

It will be appreciated by persons skilled in the art, that the herein-described rechargeable multicell battery is intended for installation, inter alia, in battery banks 120 and 122 (Figs. 7 - 8B) of an electrically powered vehicle.

In accordance with the present embodiment of the invention, and with particular reference to Fig. 23, there is illustrated a zinc-air battery cell, referenced generally 400, constructed according to an alternative embodiment of the invention. Battery cell 400 includes a pair of plastic frame members 402 typically formed of polypropylene, each supporting an outer electrode unit 404 substantially as described and shown in conjunction with Fig. 14. Accordingly, each unit 404 includes an outer current collector typically formed of nickel mesh; an air electrode, typically formed of a wet-proofed, catalyzed carbon layer bonded to nickel mesh; a porous separator, typically formed of nonwoven porous nylon; and a plastic frame. A central current collector 406 is also provided.

Referring now also to Fig. 24, there is provided a cover or base portion 408 located at a bottom end of the central current collector 406, and a slurry removal element 410 located at a top end of the central current collector. As illustrated in Fig. 23, the slurry contained within an interior storage space 411 of cell 400 is confined between the outer electrode units

404 and between the removal element 410 and the base portion 408 of the central current collector 406.

According to the illustrated embodiment, removal element 410 is a relatively rigid flange member attached to the top end of central current collector 406 such that when the central current collector is removed from the cell 400, element 410 is operative to directly engage and thus displace the bulk of the slurry contained within space 411 to the exterior. It will thus be appreciated that the slurry removal apparatus of the present embodiment is equally effective with a relatively viscous slurry as with a non-viscous slurry.

Referring now to Figs. 25A - 26, a process of removing discharged slurry from a multi-cell battery arrangement mounted in a housing 412 of one of the battery banks 120 or 122 of the body of a vehicle, such as shown and described above in conjunction with Figs. 7 - 8B, and subsequent cleaning and filling of each of the battery cells, is described below, in accordance with a preferred embodiment of the invention. A first stage is to remove the central current collector 406 of each of the cells via its base portion 408. According to one embodiment, the base portions 408 of each of the individual cells are joined or integrally formed so as to constitute a single base member, thereby facilitating the removal of all of the central current collectors simultaneously.

Referring now particularly to Fig. 25B, base portions 408 of the respective central collectors 406 are secured via first reversible actuator means 417 to a platform element 416. The platform element 416 is mounted onto second reversible actuator means 418, thereby permitting removal of the central current collector from each of a plurality of the battery cells simultaneously. As described above, removal of the central current collectors is operative to cause emptying of each of the individual cells of the discharged slurry contained therein as it is engaged and displaced by removal element 410. This is indicated schematically by arrows 405.

Depending on the viscosity of the discharged slurry, a large proportion of the discharged slurry removed from cells 400 may remain between adjacent central current collectors 406 as they are withdrawn from the cells. Accordingly, as illustrated

schematically in Figs. 25C and 27, jets 415 of a fluid, typically water or KOH, are directed between the current collectors so as to flush the slurry therefrom. Fluid jets may also be directed upward into the cells 400 so as to wash any residual discharged slurry therefrom. The removed discharged slurry is conveyed away for reconditioning as described hereinabove.

Reference is now made to Fig. 25D, in which is illustrated the step of refilling of the cells with charged slurry. A platform element 416 supports a plurality of central current collectors 406, as shown, and has mounted thereon a plurality of baths 424. Platform element 416 is typically positioned on the floor of a housing 422 via second reversible actuator means 418.

Initially, the baths 424 are filled with a volume of charged slurry 426 approximately corresponding to the volume of slurry required to fill associated cells 400.

Subsequently, second actuator means 418 are operated so as to displace the platform element 420 upwardly toward the cells 400, until sealing gaskets 427 located on the edges of baths 424 engage a lower surface 425 of the battery bank so as to define a seal therewith. Subsequently, first actuator means 417 are operated so as to displace central current collectors 406 towards cells 400. As the central current collectors are displaced toward the cells, each base portion 408, which is submerged in a volume of charged slurry, applies a generally upward pressure on the charged slurry. As baths 424 are sealed to lower surface 425 of the battery banks by gaskets 427, slurry subject to the described upward pressure is forced upward into the interior space 411 of each the cells, as depicted by arrows 431, while each central current collector 406 is reinserted into its cell. Preferably, there are also provided sealing means 419 so as to prevent leakage of slurry from cells 400 once the central current collectors 406 have been replaced therein. Suitable sealing means may be rubber gaskets, such as O-rings.

Reference is now made to Figs. 28A and 28B, in which there is illustrated a typical electric vehicle, referenced generally 500, employing rechargeable electrical power storage

apparatus, indicated generally at 502, operative and constructed in accordance with a further embodiment of the invention.

The present apparatus employs a multi-cell zinc/air battery, generally as shown and described above in conjunction with Figs. 9 - 11. It has been found that although charged zinc/air slurry has a generally liquid form, once the slurry becomes discharged, it may become very viscous so as to become virtually non-flowable. Accordingly, the present embodiment of the invention provides apparatus for causing disintegration of the virtually non-flowable discharged slurry, thereby converting it into a relatively more flowable form, so as to ease the removal thereof by pumping.

Referring now to Fig. 29, power storage apparatus 502 includes a multi-cell zinc/air battery 504, as described above, employing a plurality of cells 506, whose structure is generally as shown and described above in conjunction with Fig. 14, except that the central current collector 508 of the present embodiment, is configured, as illustrated in Fig. 32, so as to define first and second conduits, respectively referenced 510 and 512 (Figs. 31 and 32). Each cell 506 has terminals 507 and 508 (Figs. 29 and 31). Cells 506 are enclosed within a housing 509 which is open at the top and which also has bottom openings 511 so as to facilitate air circulation, generally as described hereinabove in conjunction with Figs. 9 - 11.

Referring now also to Figs. 31 and 32, first conduit 510 has a plurality of liquid outlet ports 514 (Fig. 32) through which a liquid, typically water, may be supplied to the interior space 4 9 of each cell 506 (Fig. 32). Each first conduit 510 communicates with an associated liquid inlet port 516 (Figs. 29 and 31), which is connected, via a manifold 517, to a main liquid supply conduit 518 (Figs. 29 and 30). The supply of liquid to the interior space 499 of each cell 506 is described below in greater detail.

Second liquid conduit 512 has typically a pair of first slurry ports 520 (Fig. 31) communicating with the interior of an associated cell, and is connected to a second slurry port 522 (Figs. 29 and 31). Each second slurry port 522 is associated with a main slurry conduit 524 (Figs. 2 and 30), via one of a plurality of intermediate slurry conduits 526, thereby

facilitating the supply of charged slurry to cells 506 and the removal of discharged slurry therefrom.

As will be appreciated from the ensuing description, there are provided a number of safeguards against the occurrence of electrical short-circuiting between battery cells 506. With particular reference to Fig. 30, one such safeguard is provided by the clearance between inlet/outlet ports 529 of intermediate conduits 526, located in an upper portion 533 of main conduit 524, and a floor portion 537 thereof.

Therefore, if charged slurry from the battery cells 506 backs up through two or more intermediate conduits 526 and exits through inlet/outlet ports 529, as the slurry exits the ports 529, it falls, under the influence of gravity, away from ports 529, so as to become electrically isolated from the slurry remaining within the battery cells, thereby preventing electrical short-circuiting between battery cells.

Referring now generally to Figs. 28A - 32, a process of discharged slurry replacement, according to the present embodiment of the invention, is described. A first step in the process is to halt electrochemical activity within the hitherto electrochemically active battery 504. In the present embodiment, this is done by supplying an inert, non-reactive gas, e.g. nitrogen, from an external source 550 (Fig. 28B) such as a suitable gas or storage tank via a gas supply line 528 (Fig. 28B), to the air circulation system of the battery 504. The air circulation system of the battery is not illustrated herein in detail, but is typically similar to the air circulation system shown and described above in conjunction with Figs. 9 - 11. The described supply of the inert gas starves the battery cells 506 of air so as to halt electrochemical activity in the battery, thereby preventing electrical short-circuiting during the replacement of the discharged slurry, described below.

There is typically also provided a container 530 (Fig. 28B) of the inert, non-reactive gas from which gas may be supplied automatically to the air conduit system of the battery so as to halt electrochemical activity thereof, upon the occurrence of a breakdown in the operation of the vehicle 500. This is shown schematically by arrow 552 (Fig. 28B).

Thereafter, a preferred flushing liquid, typically water or KOH, is supplied from an external source (not shown) to the interior of the plurality of cells 506, via a liquid supply line 532 (Fig. 28B), main liquid supply conduit 518, manifold 517, liquid inlet ports 516, and first conduits 510, exiting through liquid outlet ports 514 (Fig. 32) in the form of liquid jets of a predetermined configuration. The liquid jets are operative to cause mechanical disintegration of the discharged slurry in the cells. Particles of the disintegrated slurry thus become suspended in the flushing liquid, so that when a pressure differential is applied across the cells, as by any suitable pumping means 515 (Fig. 28B), suction removal of the particle/liquid mixture occurs.

The particle/liquid mixture is removed from the cells via first slurry ports 520, second conduits 512, second slurry ports 522, intermediate slurry conduits 526 and main slurry conduit 524. According to one embodiment of the invention, the flushing liquid is supplied in the form of a pulsed flow so as to more rapidly disintegrate the discharged slurry. The discharged slurry is removed from battery 504 via a slurry outlet line 534 (Fig. 28B) and is then sent for reconditioning as described above.

After the discharged slurry has been removed from the cells, flow of the flushing liquid is halted, although, according to a preferred embodiment of the invention, when the vehicle 500 is in use, liquid is supplied at a very low volumetric flow rate to the interior of the cells from a container 536 (Figs. 28A and 28B) via first conduits 510, so as to prevent the slurry in the cells from drying out. The empty battery cells 506 are filled with charged slurry supplied, for example, from fill in unit 66 (Fig. 3). The charged slurry is provided via a slurry supply line 538 (Fig. 28B), main slurry conduit 524, intermediate slurry conduits 526, second slurry ports 522, second conduits 512. and first slurry ports 520.

Referring once again briefly to Fig. 30, according to the present embodiment, main slurry conduit 524 defines multiple helical grooves 525. It will be appreciated that the helical grooves 525 assist in the flow of flushing liquid in which discharged slurry particles are suspended and in the flow of

the charged slurry when refilling cells 506. Flushing of the main slurry conduit, as described above, is also aided by the presence of the grooves 525.

After the battery cells have been filled with charged slurry, main conduit 524 is flushed with a liquid supplied via slurry supply line 538 (Fig. 28B) so as to clean traces of slurry from main conduit 524. Subsequently, inert, non-reactive gas is passed through the main conduit so as to dry it, and finally, the main conduit is closed by suitable valve means so as to entrap therein a volume of the inert gas, thereby providing a safeguard against electrical short-circuiting between battery cells 506.

With further reference to Fig. 28A, vehicle 500 typically also includes an air filter 540, a CO_2 scrubber 542, air inlet 544 and air outlet 548 communicating with the air conduit system of the battery. Air filter 540, CO_2 scrubber 542 and air conduits 544 facilitate the supply of air to battery 504, substantially as described above in relation to the embodiments of Figs. 6, 18, 19 and 20. There are also provided vehicle control systems, including a computerized electric motor controller 546, an electrical connection box 548 and an electrical cable 550 connecting between battery 504 and controller 546.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow:

CLAIMS

1. Rechargeable electrical power storage apparatus comprising:

an electrical power storage unit having at least one rechargeable electrical cell containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state;

means for converting the discharged storage medium from a relatively less flowable form to a relatively more flowable form; and

means for removing the discharged storage medium in said relatively more flowable form from said at least one cell.

2. Apparatus according to claim 1, and wherein said means for removing comprises means for pumping the discharged storage medium in said relatively more flowable form from said at least one cell.

3. Apparatus according to claim 1, and wherein said means for converting comprises means for causing disintegration of the discharged storage medium in said relatively less flowable form.

4. Apparatus according to claim 3, and wherein said means for causing disintegration comprises means for directing jets of a liquid at the discharged storage medium contained in said at least one cell, thereby causing disintegration of the discharged storage medium into particles, thereby resulting in a particle/liquid suspension.

5. Apparatus according to claim 4, and wherein said means for removing comprises means for pumping the particle/liquid suspension from said at least one cell.

6. Apparatus according to claim 5, and wherein said means for pumping comprises:

a pump; and

conduit means associated with said pump and with each said cell.

7. Apparatus according to claim 5, and wherein said means for pumping is operatively associated with a supply of charged power storage medium so as to supply a predetermined volume of the charged power storage medium to each said cell.

8. Apparatus according to claim 7, and wherein each said cell is a metal/air cell, the power storage medium is a metal/air slurry, and said electrical power storage unit also comprises an air conduit system for permitting air flow in operative association with each said cell.

9. Apparatus according to claim 8, and wherein each said cell comprises a zinc/air cell and the slurry is a zinc/air slurry.

10. Apparatus according to claim 8, and also including means for selectably preventing electrochemical activity of said electrical power storage unit.

11. Apparatus according to claim 10, and wherein said means for preventing electrochemical activity comprises means for supplying an inert, non-reactive gas to said air conduit system, thereby preventing the supply of air to each said cell.

12. Apparatus according to claim 11, and wherein said gas is nitrogen gas.

13. Apparatus according to claim 1, and wherein said at least one rechargeable electrical cell comprises a plurality of rechargeable cells.

14. Apparatus according to claim 6, and wherein said at least one rechargeable electrical cell comprises a plurality of rechargeable electrical cells and said conduit means comprises:

a main supply conduit arranged to extend transversely to the direction of gravitational acceleration and defining upper and lower inward-facing portions; and

at least one intermediate supply conduit extending between said main supply conduit and said plurality of cells, each said intermediate supply conduit defining an opening communicating with the interior of said main supply conduit and spaced from said lower surface thereof such that charged storage medium backing up through said at least one intermediate supply conduit is operative, as it exits from said port, to fall generally downward, away from said port toward said lower surface of said main conduit, thereby becoming electrically isolated from said plurality of cells.

15. An electrical transport system comprising:

an electrically powered vehicle having vehicle drive means;

rechargeable electrical power storage apparatus electrically coupled to said vehicle drive means, and including at least one rechargeable electrical cell containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state;

means for converting the discharged storage medium from a relatively less flowable form to a relatively more flowable form; and

means for removing the discharged storage medium in said relatively more flowable form from said at least one cell.

16. A system according to claim 15, and wherein said means for removing comprises means for pumping the discharged storage medium in said relatively more flowable form from said at least one cell.

17. A system according to claim 15, and wherein said means for converting comprises means for causing disintegration of the discharged storage medium in relatively less flowable form.

18. A system according to claim 17, and wherein said means for causing disintegration comprises means for directing jets of a liquid at the discharged storage medium contained in said at least one cell, thereby causing disintegration of the discharged storage medium into particles, thereby resulting in a particle/liquid suspension.

19. A system according to claim 18, and wherein said means for removing comprises means for pumping the particle/liquid suspension from said at least one cell.

20. A system according to claim 19, and wherein said means for pumping comprises:

a pump; and

conduit means associated with said pump and with each said cell.

21. A system according to claim 19, and wherein said means for pumping is operatively associated with a supply of charged power storage medium so as to supply a predetermined volume of the charged power storage medium to each said cell.

22. A system according to claim 21, and wherein each said cell is a metal/air cell, the power storage medium is a

metal/air slurry, and said electrical power storage unit also comprises an air conduit system for permitting air flow in operative association with each said cell.

23. A system according to claim 22, and wherein each said cell comprises a zinc/air cell and the slurry is a zinc/air slurry.

24. A system according to claim 22, and also including means for selectably preventing electrochemical activity of said electrical power storage unit.

25. A system according to claim 24, and wherein said means for preventing electrochemical activity comprises means for supplying an inert, non-reactive gas to said air conduit system, thereby preventing the supply of air to each said cell.

26. A system according to claim 25, and wherein said gas is nitrogen gas.

27. A system according to claim 15, and wherein said at least one rechargeable electrical cell comprises a plurality of rechargeable cells.

28. A system according to claim 20, and wherein said at least one rechargeable electrical cell comprises a plurality of rechargeable electrical cells and said conduit means comprises:

a main supply conduit arranged to extend transversely to the direction of gravitational acceleration and defining upper and lower inward-facing portions; and

at least one intermediate supply conduit extending between said main supply conduit and said plurality of cells, each said intermediate supply conduit defining an opening communicating with the interior of said main supply conduit and spaced from said lower surface thereof such that charged storage medium backing up through said at least one intermediate supply conduit is operative, as it exits from said port, to fall generally downward, away from said port toward said lower surface of said main conduit, thereby becoming electrically isolated from said plurality of cells.

29. An electrical energy system comprising:

an electric utility having electricity generation apparatus and distribution lines;

a plurality of electric vehicles, each having vehicle drive means;

a rechargeable electrical power storage unit electrically coupled to said vehicle drive means, and including at least one rechargeable electrical cell containing a rechargeable electrical power storage medium, the storage medium being relatively more flowable when in a charged state and relatively less flowable when in a discharged state;

means for converting the discharged storage medium from a relatively less flowable form to a relatively more flowable form;

means for removing the discharged storage medium in said relatively more flowable form from said at least one cell; and

electric power storage means receiving electrical power from the electric utility and supplying electrical power to each said rechargeable electrical power storage unit and to the electric utility when required.

30. A system according to claim 29, and wherein said means for removing comprises means for pumping the discharged storage medium in said relatively more flowable form from said at least one cell.

31. A system according to claim 29, and wherein said means for converting comprises means for causing disintegration of the discharged storage medium in said relatively less flowable form.

32. A system according to claim 31, and wherein said means for causing disintegration comprises means for directing jets of a liquid at the discharged storage medium contained in said at least one cell, thereby causing disintegration of the discharged storage medium into particles, thereby resulting in a particle/liquid suspension.

33. A system according to claim 32, and wherein said means for removing comprises means for pumping the particle/liquid suspension from said at least one cell.

34. A system according to claim 33, and wherein said means for pumping comprises:

a pump; and

conduit means associated with said pump and with each said cell.

35. A system according to claim 33, and wherein said means for pumping is operatively associated with a supply of charged power storage medium so as to supply a predetermined volume of the charged power storage medium to each said cell.

36. A system according to claim 35, and wherein each said cell is a metal/air cell, the power storage medium is a metal/air slurry, and said electrical power storage unit also comprises an air conduit system for permitting air flow in operative association with each said cell.

37. A system according to claim 36, and wherein each said cell comprises a zinc/air cell and the slurry is a zinc/air slurry.

38. A system according to claim 36, and also including means for selectably preventing electrochemical activity of said electrical power storage unit.

39. A system according to claim 38, and wherein said means for preventing electrochemical activity comprises means for supplying an inert, non-reactive gas to said air conduit system, thereby preventing the supply of air to each said cell.

40. A system according to claim 39, and wherein said gas is nitrogen gas.

41. A system according to claim 29, and wherein said at least one rechargeable electrical cell comprises a plurality of rechargeable cells.

42. A system according to claim 34, and wherein said at least one rechargeable electrical cell comprises a plurality of rechargeable electrical cells and said conduit means comprises:

a main supply conduit arranged to extend transversely to the direction of gravitational acceleration and defining upper and lower inward-facing portions; and

at least one intermediate supply conduit extending between said main supply conduit and said plurality of cells, each said intermediate supply conduit defining an opening communicating with the interior of said main supply conduit and spaced from said lower surface thereof such that charged storage medium backing up through said at least one intermediate supply conduit is operative, as it exits from said port, to fall generally downward, away from said port toward said lower

surface of said main conduit, thereby becoming electrically isolated from said plurality of cells.

43. A system according to claim 29, and wherein said electric power storage means is operative to receive electrical power from the electrical utility at off-peak times and to provide electrical power to the electrical utility at peak demand times.

44. A system according to claim 29, and wherein said electric power storage means includes surge switching means for enabling the electric power storage apparatus to absorb undesired power surges from the electrical utility in real time or near real time.

45. A system according to claim 29, and wherein said electric power storage means is operative to provide electrical power to the electrical utility at peak and super peak demand.

46. A system according to claim 29, and wherein said electric power storage means is operative to provide electrical power to the electrical utility at real or near real time to serve as a spinning reserve.

47. A system according to claim 29, and wherein said electric power storage means includes electrical power storage units employing a liquid-like metal/air slurry as a rechargeable electrical energy storage medium.

48. A system according to claim 47, and wherein said electrical power storage units coupled to said vehicle drive means are employed for relatively more frequent charging and discharging, while said electrical power storage units of said electric power storage means are employed for less frequent charging and discharging.

49. A system according to claim 29, and also comprising an electric vehicle recharging depot including apparatus for removing discharged slurry from vehicles and supplying it to a storage facility to await off-peak recharging and means for supplying recharged slurry to vehicles from the electric power storage apparatus.

50. A method of recharging a rechargeable electrical power storage unit having at least one electrical power storage cell, each containing a rechargeable electrical power storage medium which is relatively more flowable when in a charged state and

relatively less flowable when in a discharged state, said method comprising the following steps:

converting the discharged storage medium from a relatively less flowable form to a relatively more flowable form;

removing the discharged storage medium in said relatively more flowable form from said at least one cell; and

supplying charged storage medium to said at least one cell.

51. A method according to claim 50, and wherein said step of removing comprises the step of pumping the discharged storage medium insaid relatively more flowable form from said at least one cell.

52. A method according to claim 50, and wherein said step of converting comprises the step of causing disintegration of the discharged storage medium in said relatively less flowable form.

53. A method according to claim 52, and wherein said step of causing disintegration comprises the step of directing jets of a liquid at the discharged storage medium contained in said at least one cell so as to cause disintegration of the discharged storage medium into particles, thereby resulting in a particle/liquid suspension.

54. A method according to claim 53, and wherein said step of removing comprises the step of pumping the particle/liquid suspension from said at least one cell.

55. A method according to claim 54, and wherein each said cell is a metal/air cell, the power storage medium is a metal/air slurry, and said method also includes the step of preventing electrochemical activity of said electrical power storage unit during said steps of removing and supplying.

56. A method according to claim 55, and wherein said step of preventing electrochemical activity comprises the step of circulating an inert, non-reactive gas about each said cell each said cell so as to prevent the supply of air thereto.

57. A method according to claim 56, and wherein said step of circulating a gas comprises the step of circulating nitrogen gas.

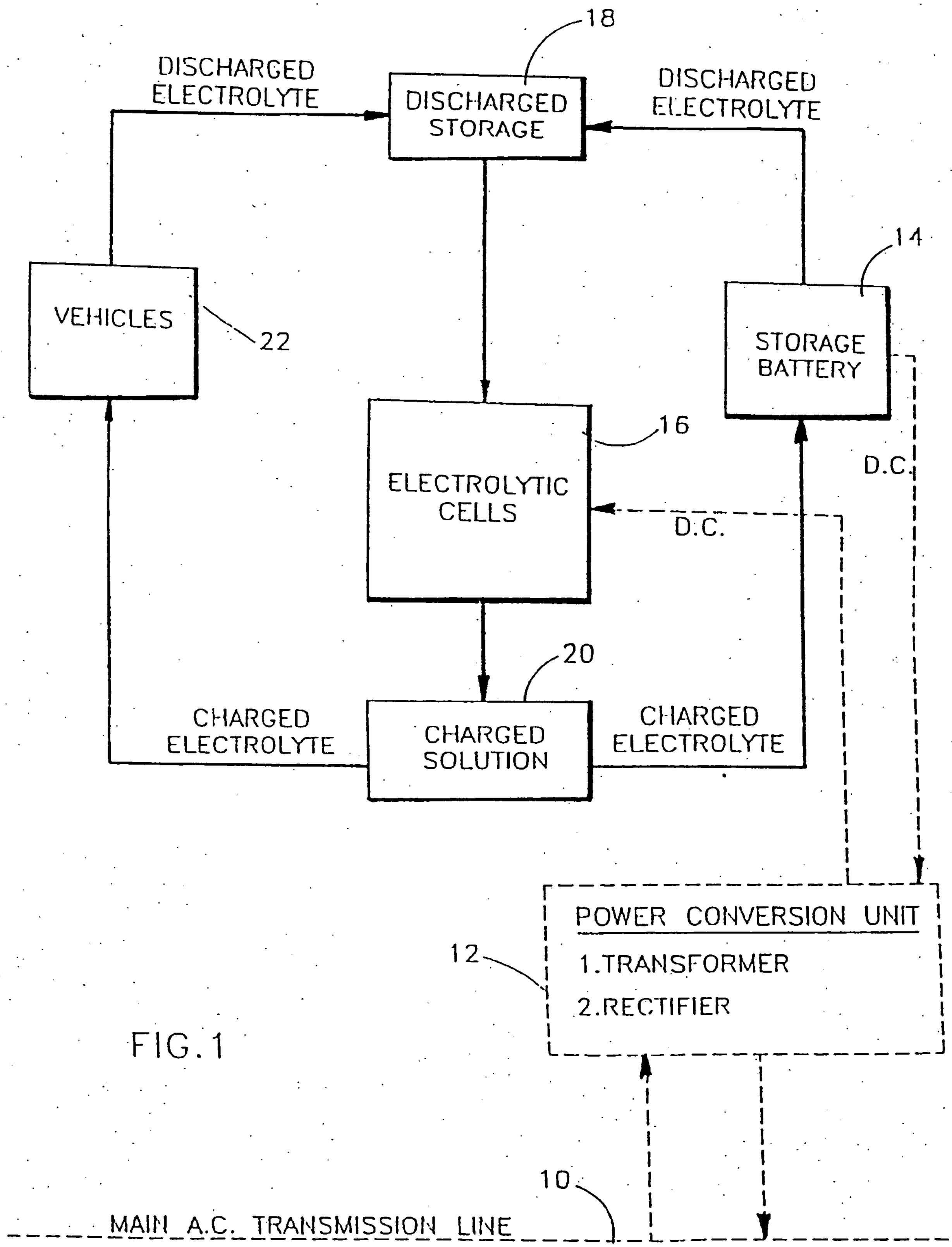
18
DISCHARGED ELECTROLYTE
DISCHARGED STORAGE
DISCHARGED ELECTROLYTE
VEHICLES
22
14
STORAGE BATTERY
16
ELECTROLYTIC CELLS
D.C.
D.C.
20
CHARGED ELECTROLYTE
CHARGED SOLUTION
CHARGED ELECTROLYTE
POWER CONVERSION UNIT
1.TRANSFORMER
2.RECTIFIER
12
10
MAIN A.C. TRANSMISSION LINE

FIG.1

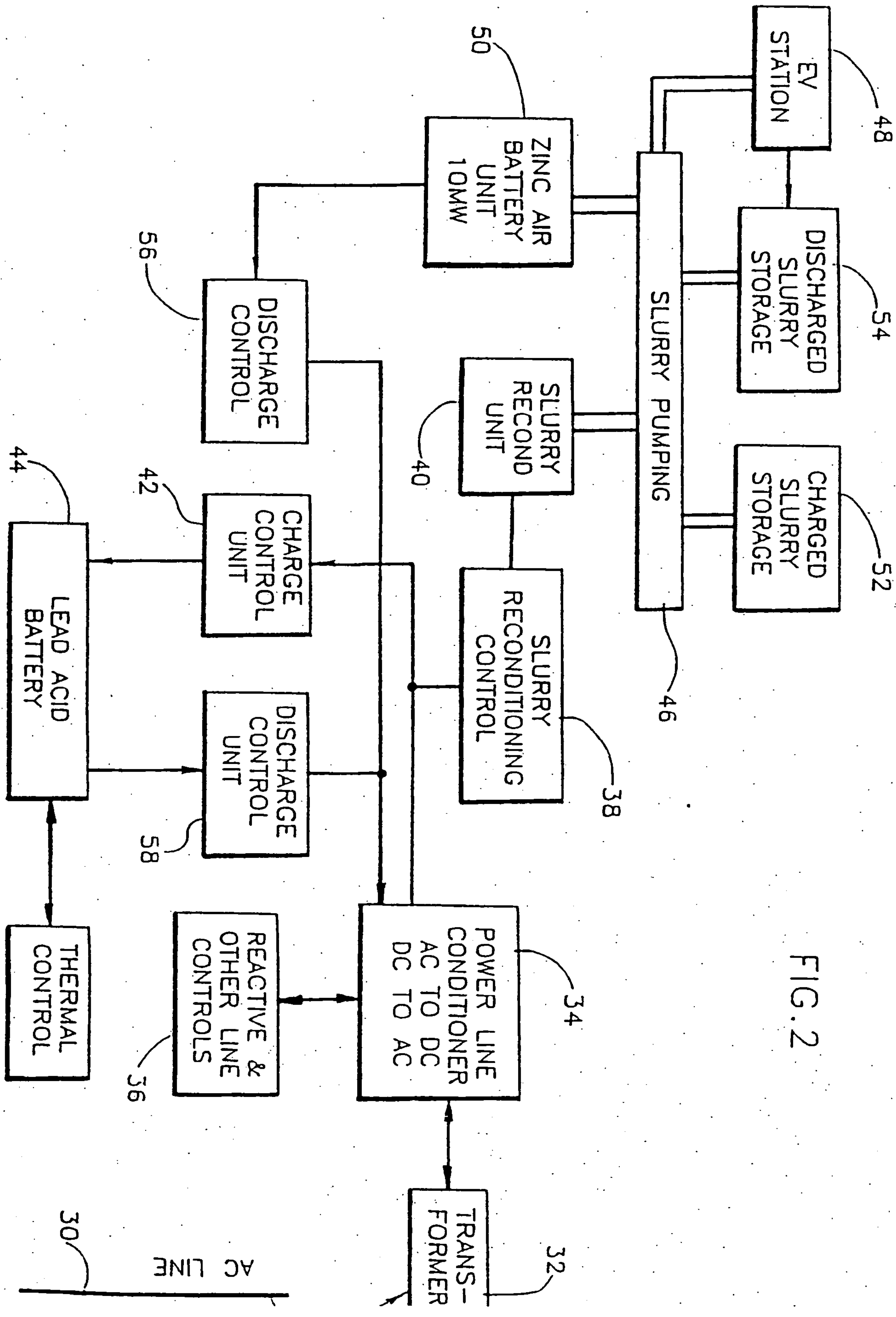
EV STATION
48
50
ZINC AIR BATTERY UNIT 10MW
DISCHARGED SLURRY STORAGE
54
SLURRY PUMPING
56
DISCHARGE CONTROL
SLURRY RECOND UNIT
40
CHARGED SLURRY STORAGE
52
44
42
CHARGE CONTROL UNIT
LEAD ACID BATTERY
SLURRY RECONDITIONING CONTROL
46
DISCHARGE CONTROL UNIT
38
58
THERMAL CONTROL
REACTIVE & OTHER LINE CONTROLS
POWER LINE CONDITIONER AC TO DC DC TO AC
34
36
TRANS-FORMER
32
30
AC LINE

FIG. 2

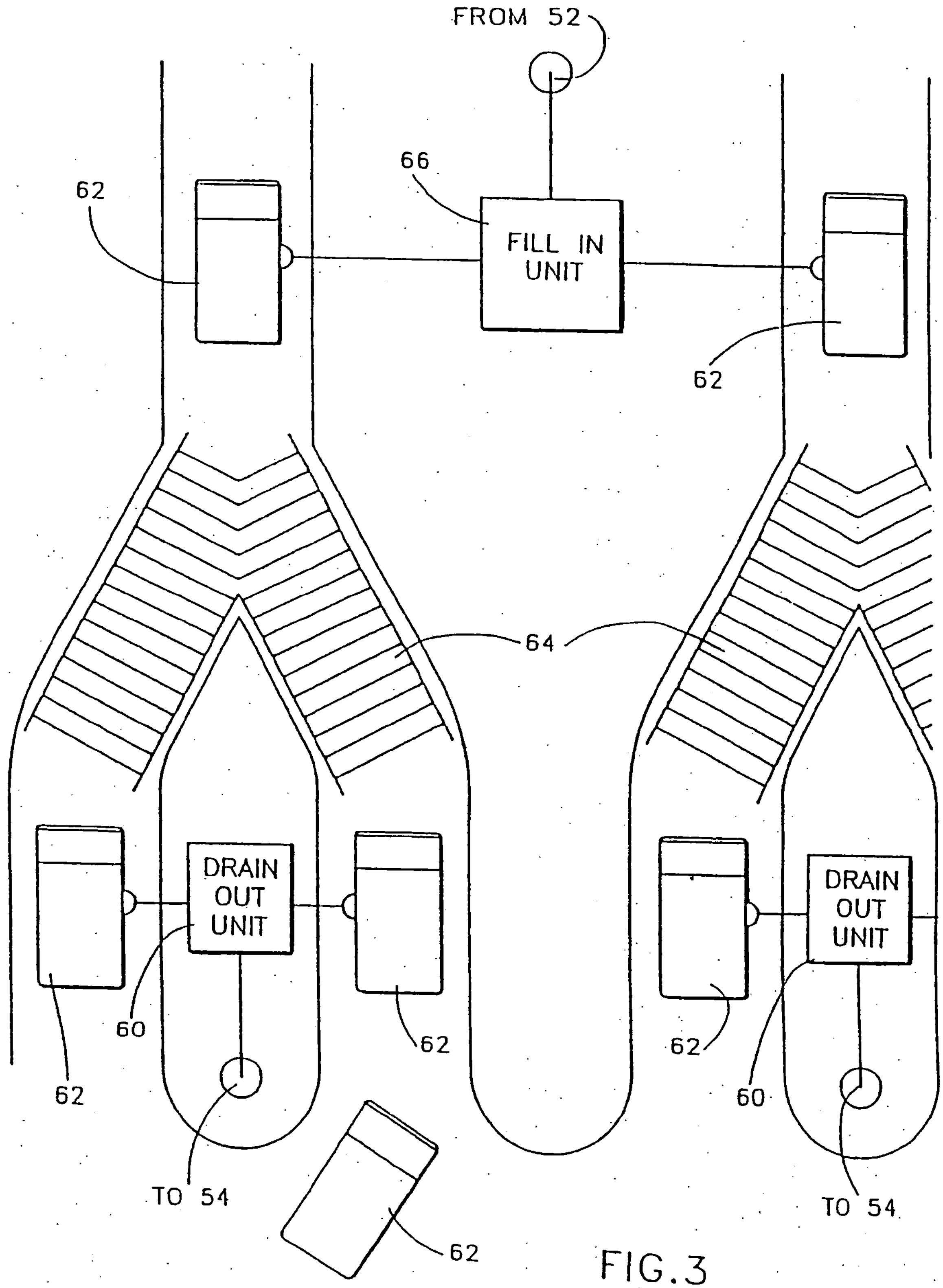
FROM 52
66
FILL IN UNIT
62
62
64
DRAIN OUT UNIT
DRAIN OUT UNIT
60
62
62
62
62
60
TO 54
TO 54
62

FIG.3

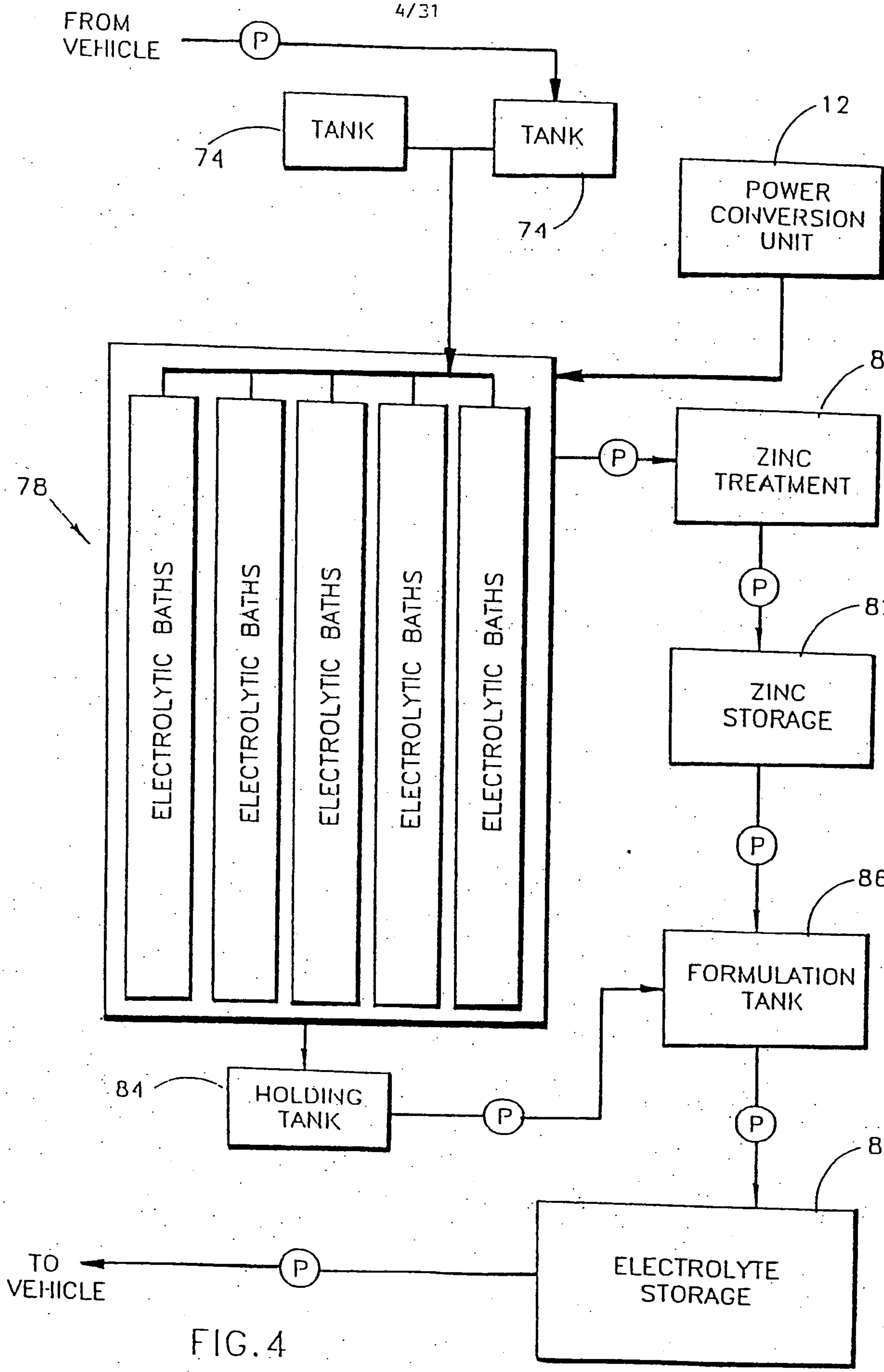
FROM VEHICLE
P
TANK
TANK
74
74
12
POWER CONVERSION UNIT
80
78
ELECTROLYTIC BATHS
ELECTROLYTIC BATHS
ELECTROLYTIC BATHS
ELECTROLYTIC BATHS
ELECTROLYTIC BATHS
ZINC TREATMENT
82
ZINC STORAGE
86
FORMULATION TANK
84
HOLDING TANK
88
ELECTROLYTE STORAGE
TO VEHICLE

FIG. 4

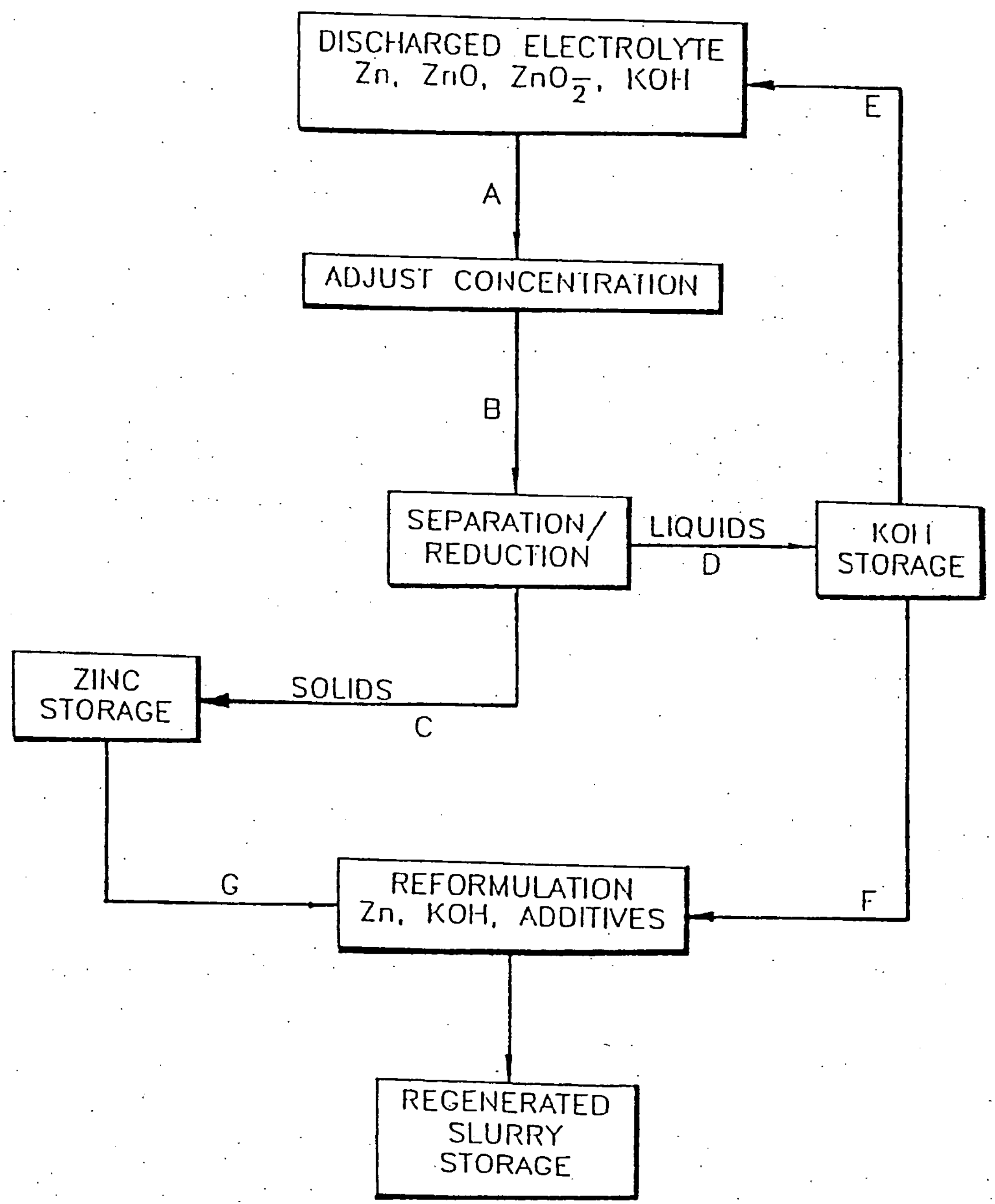
DISCHARGED ELECTROLYTE
Zn, ZnO, ZnO_2^-, KOH
A
ADJUST CONCENTRATION
B
SEPARATION/ REDUCTION
LIQUIDS
D
KOH STORAGE
E
SOLIDS
C
ZINC STORAGE
G
REFORMULATION Zn, KOH, ADDITIVES
F
REGENERATED SLURRY STORAGE

FIG.5

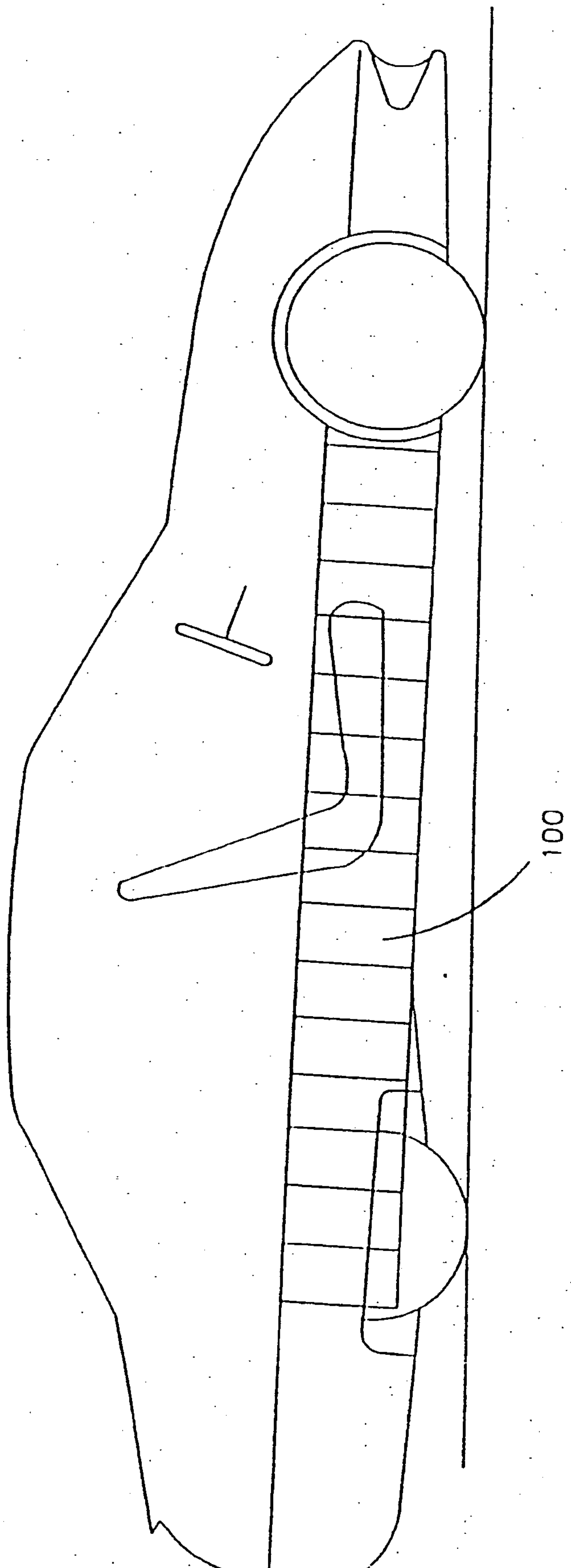

FIG.6

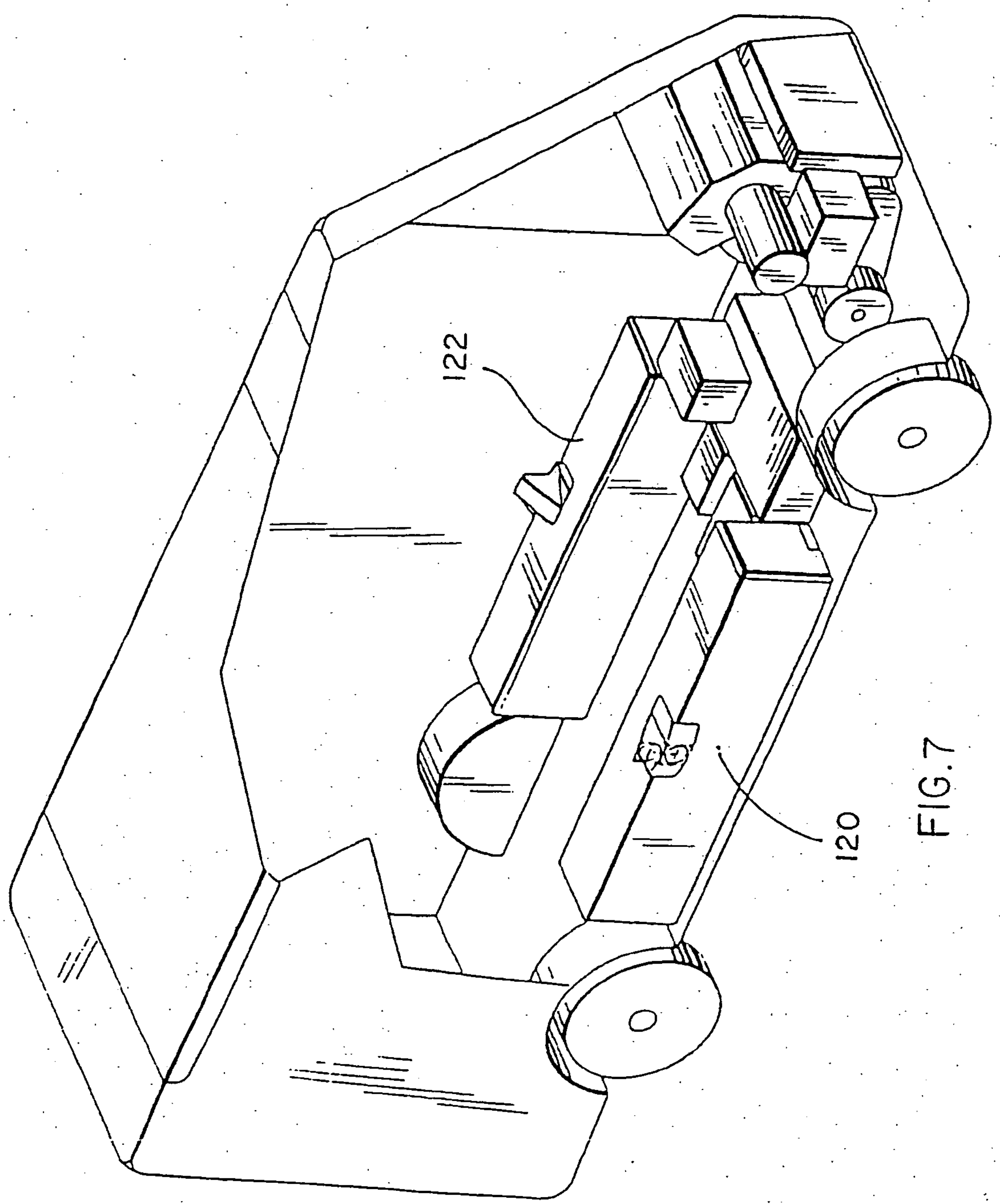

FIG.7

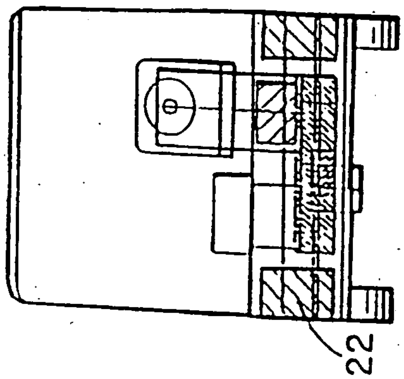

FIG.8C

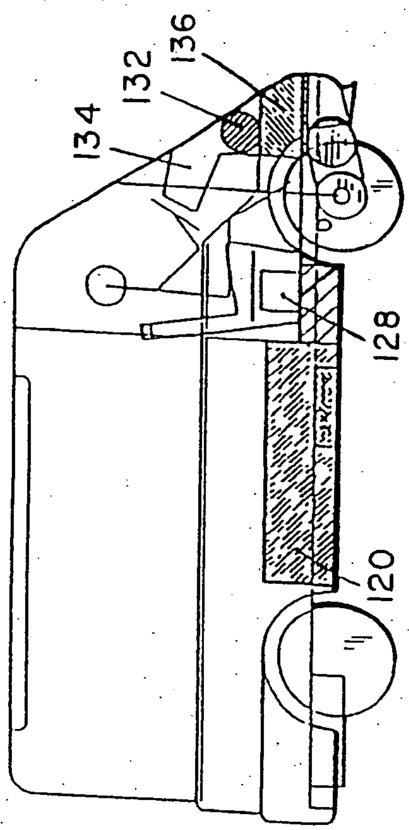

FIG.8A

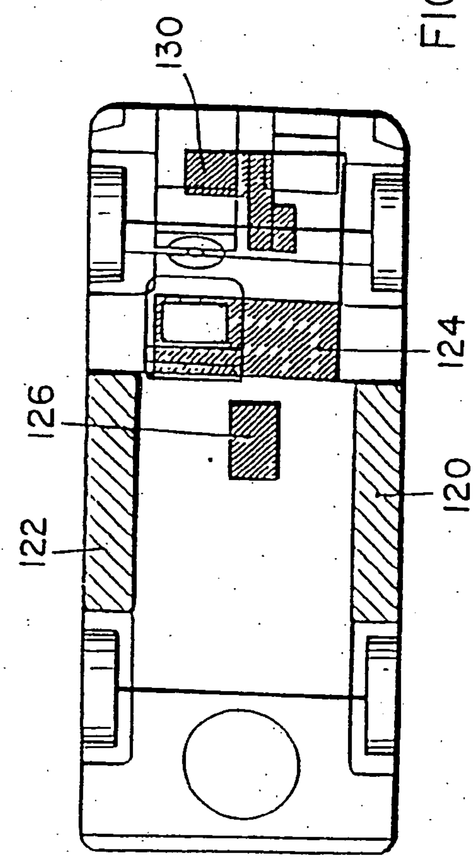

FIG.8B

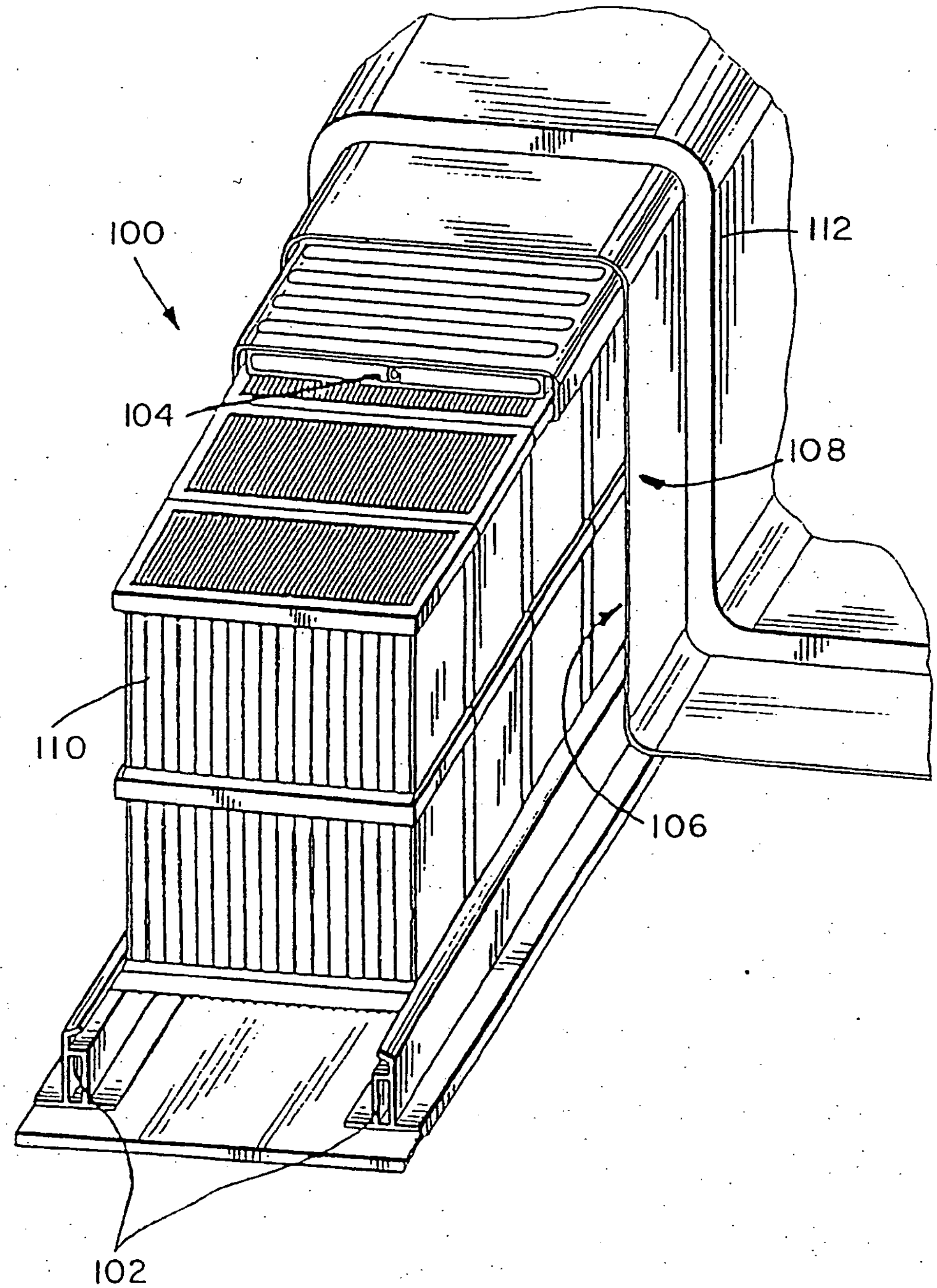

FIG.9

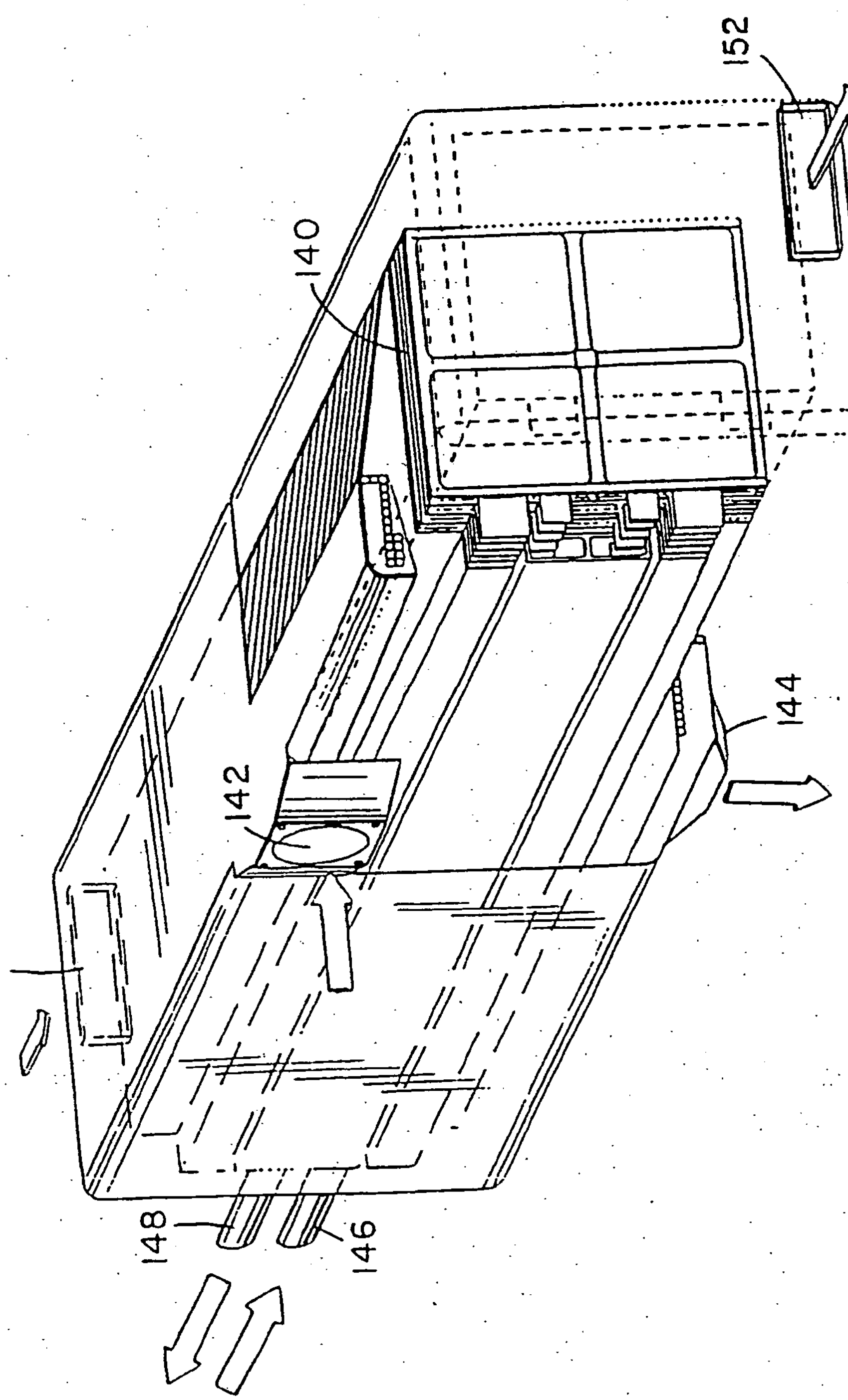

FIG.10

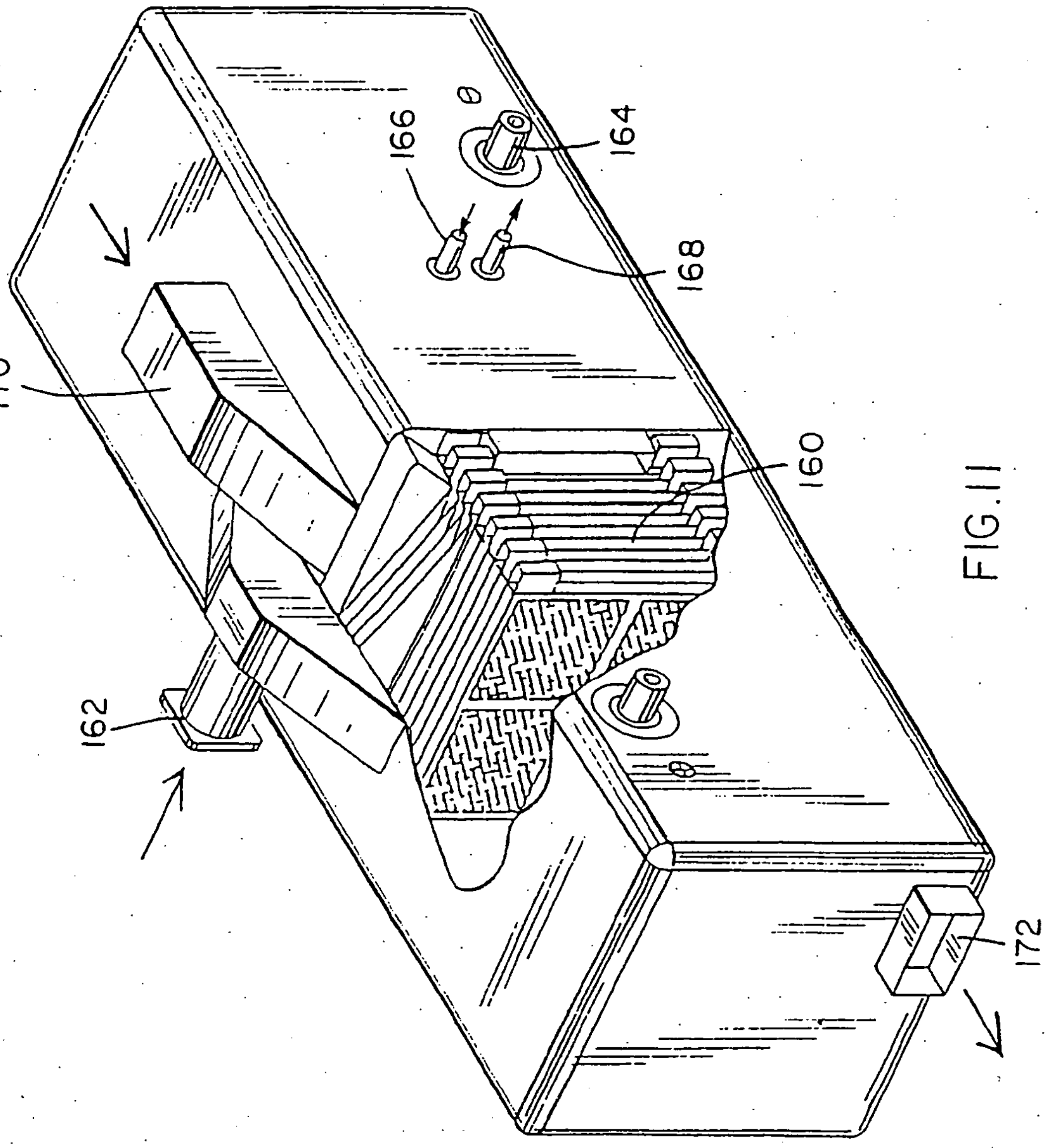

FIG.11

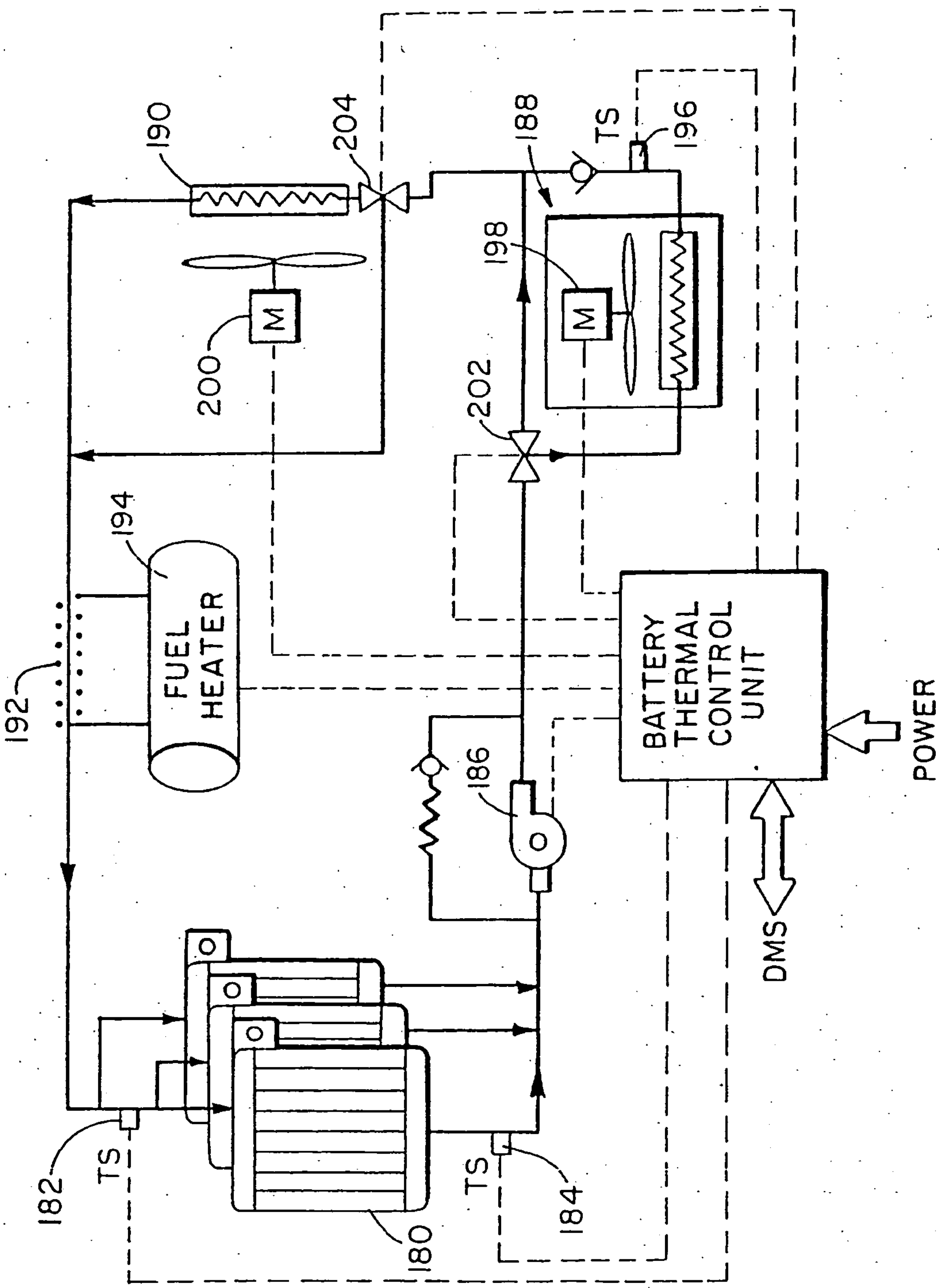
190
204
188
TS
196
198
M
200
M
202
194
FUEL HEATER
192
BATTERY THERMAL CONTROL UNIT
186
POWER
DMS
182
TS
TS
184
180

FIG.12

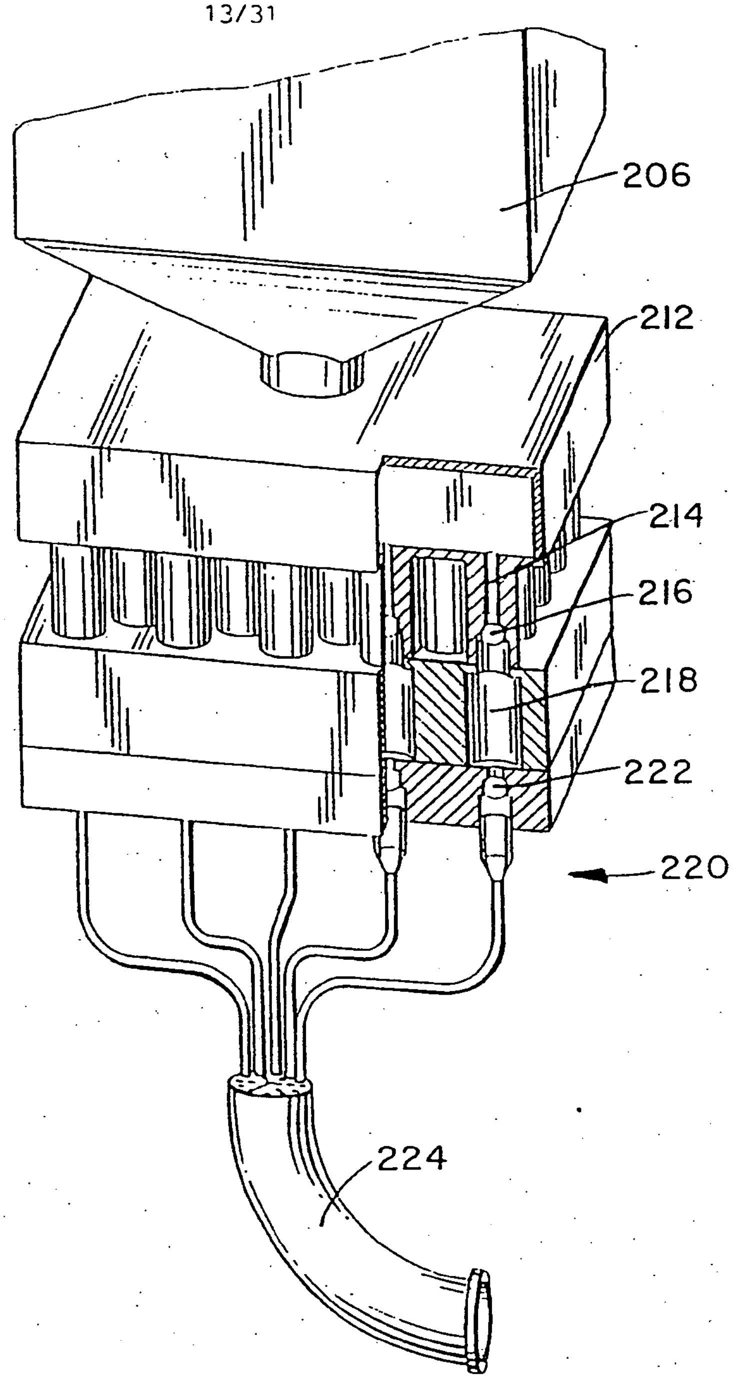

FIG.13

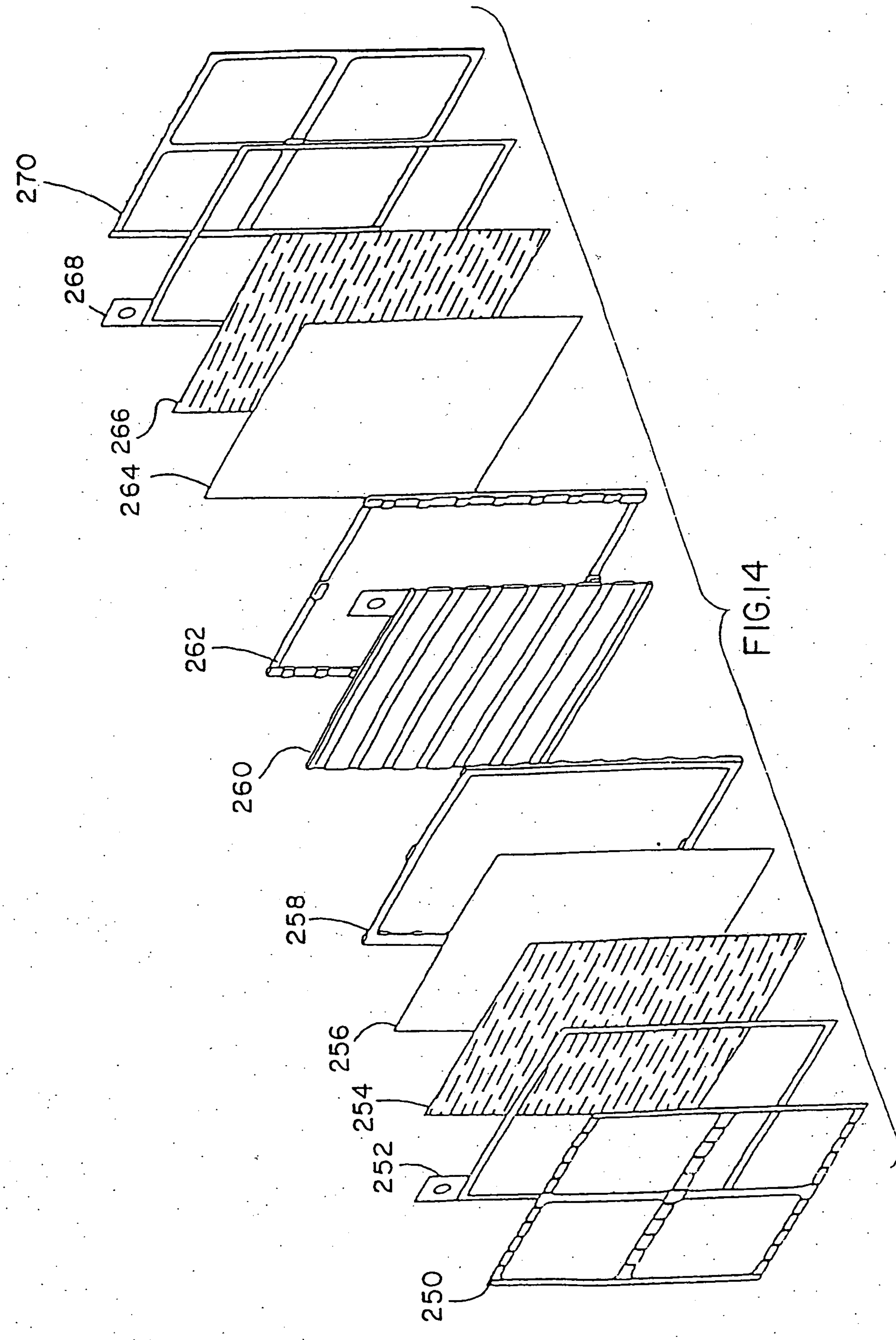

FIG.14

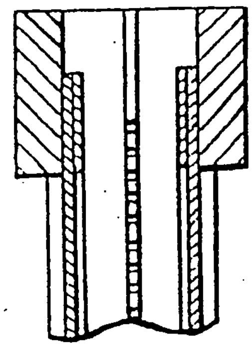

FIG. 15

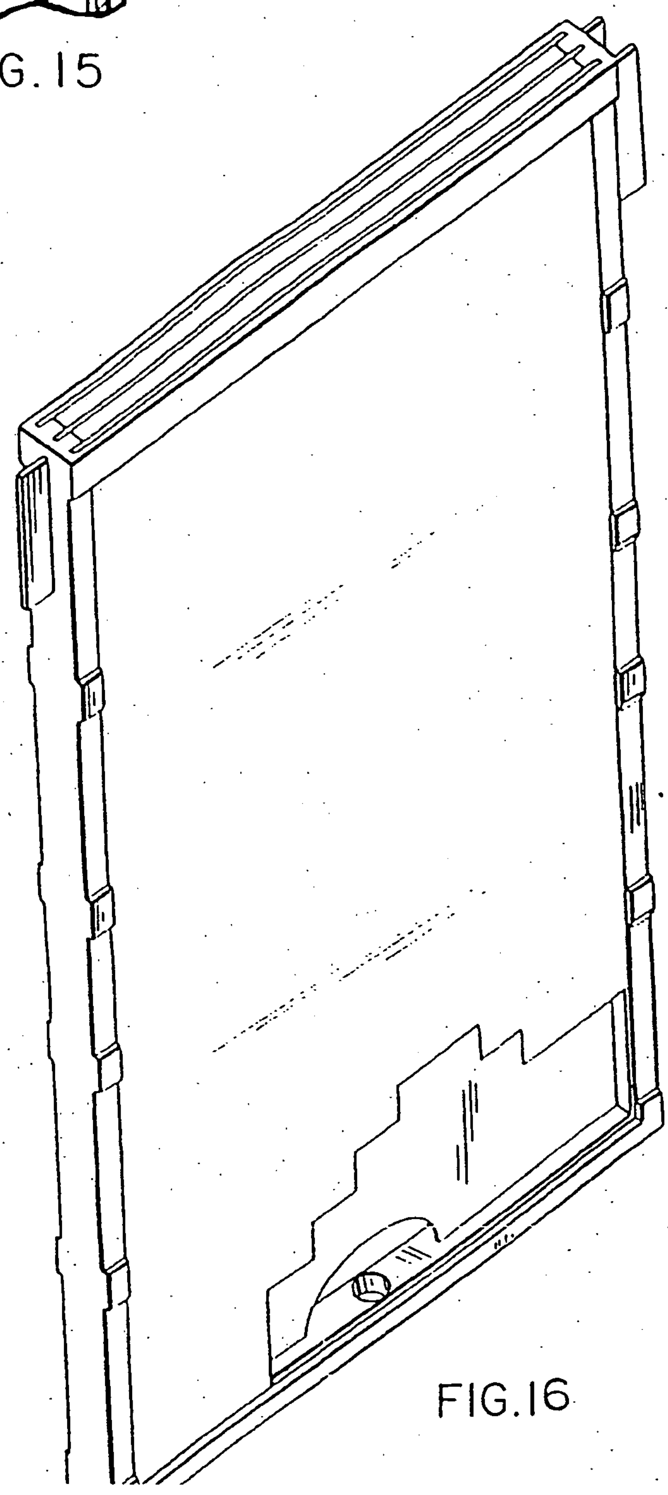

FIG. 16

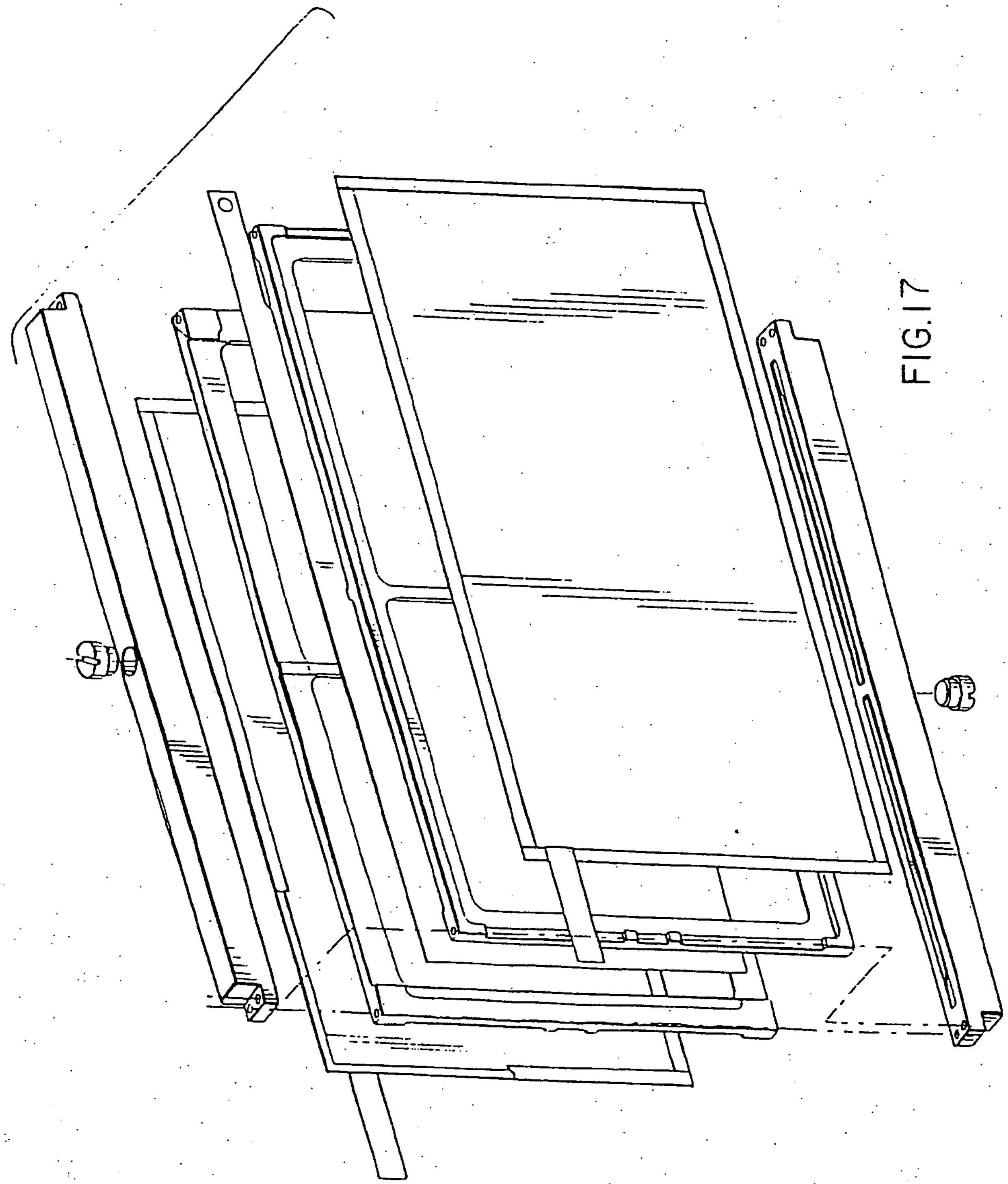

FIG.17

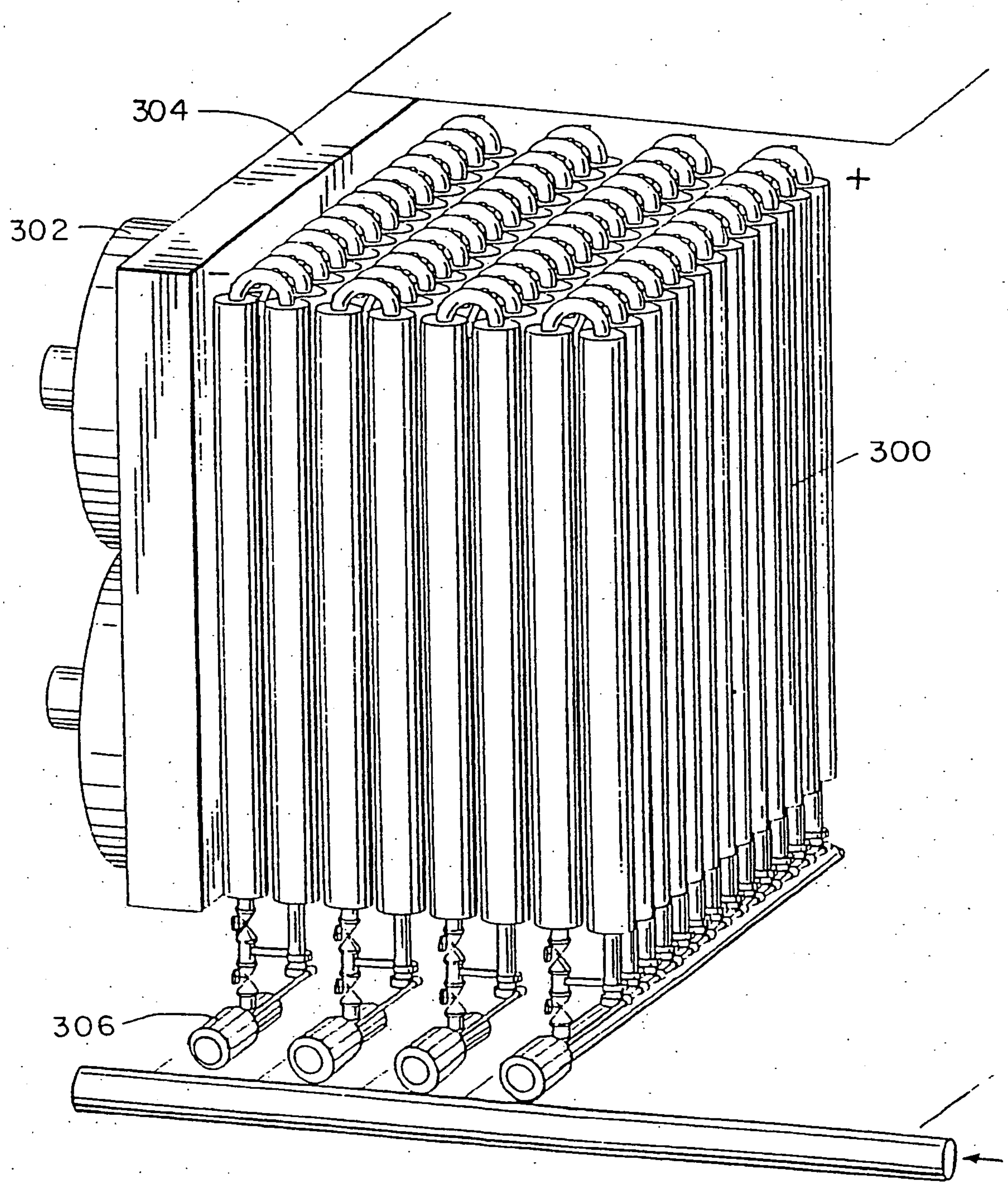

FIG.18

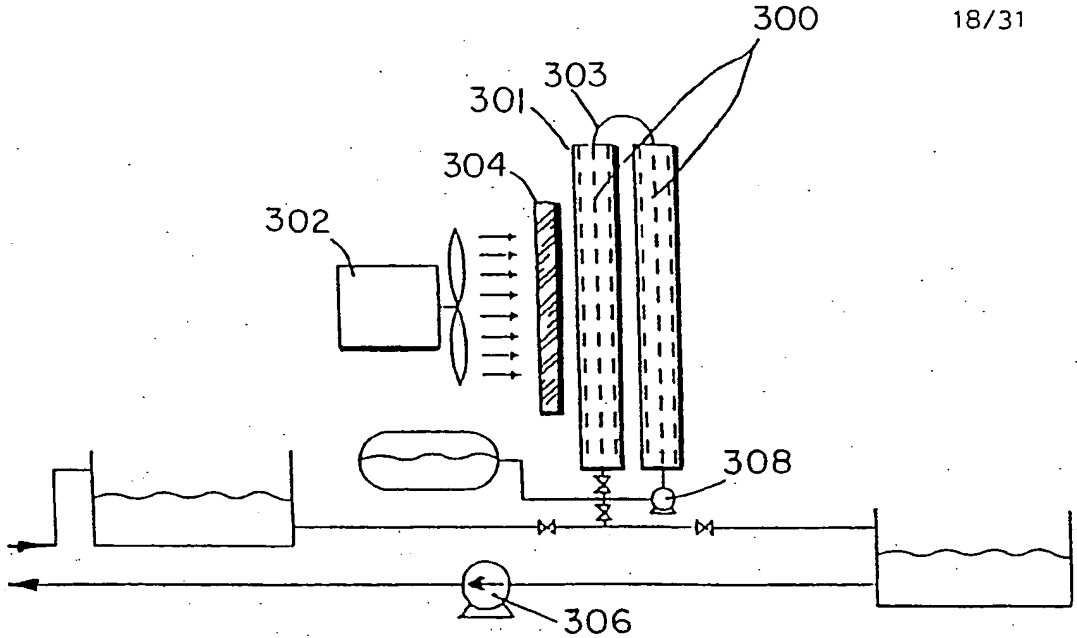
300
303
301
304
302
308
306

FIG.19

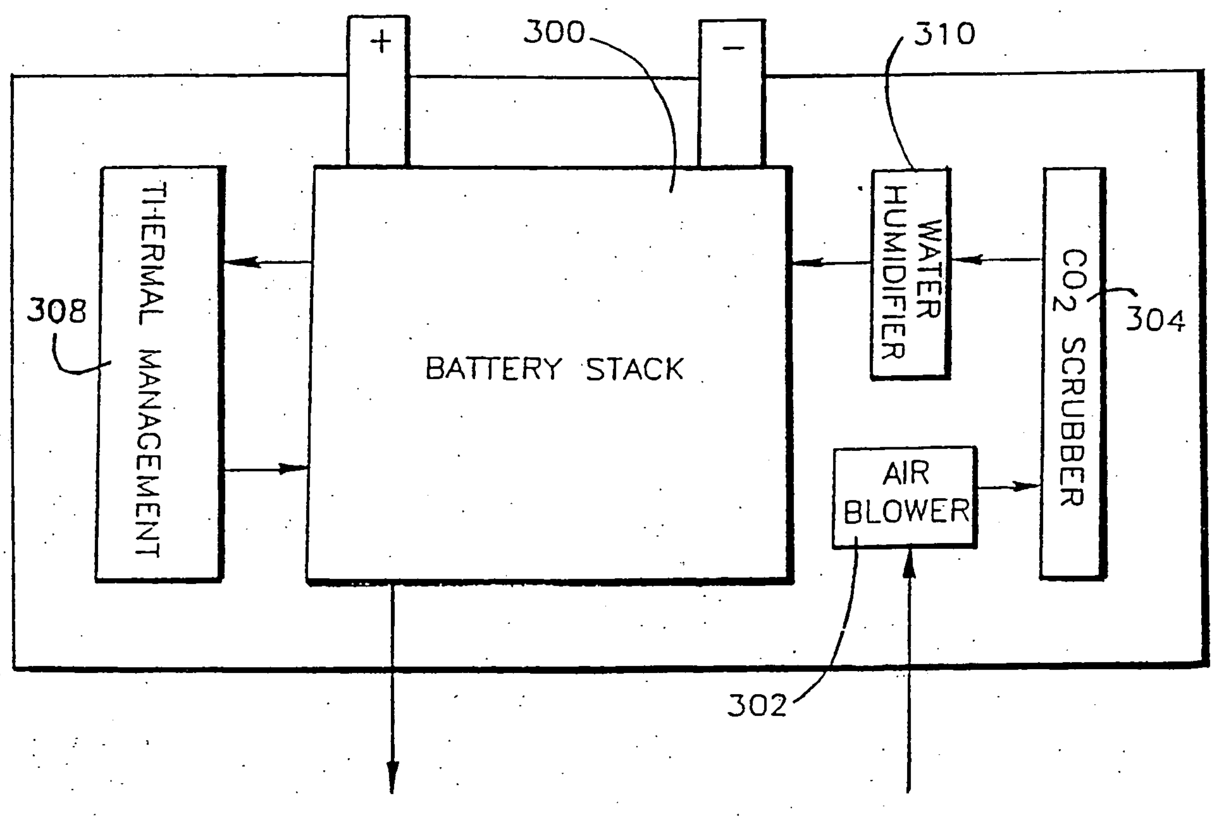
+
300
−
310
THERMAL MANAGEMENT
308
BATTERY STACK
WATER HUMIDIFIER
CO2 SCRUBBER
304
AIR BLOWER
302
AIR OUTLET
AIR INTAKE

FIG.20

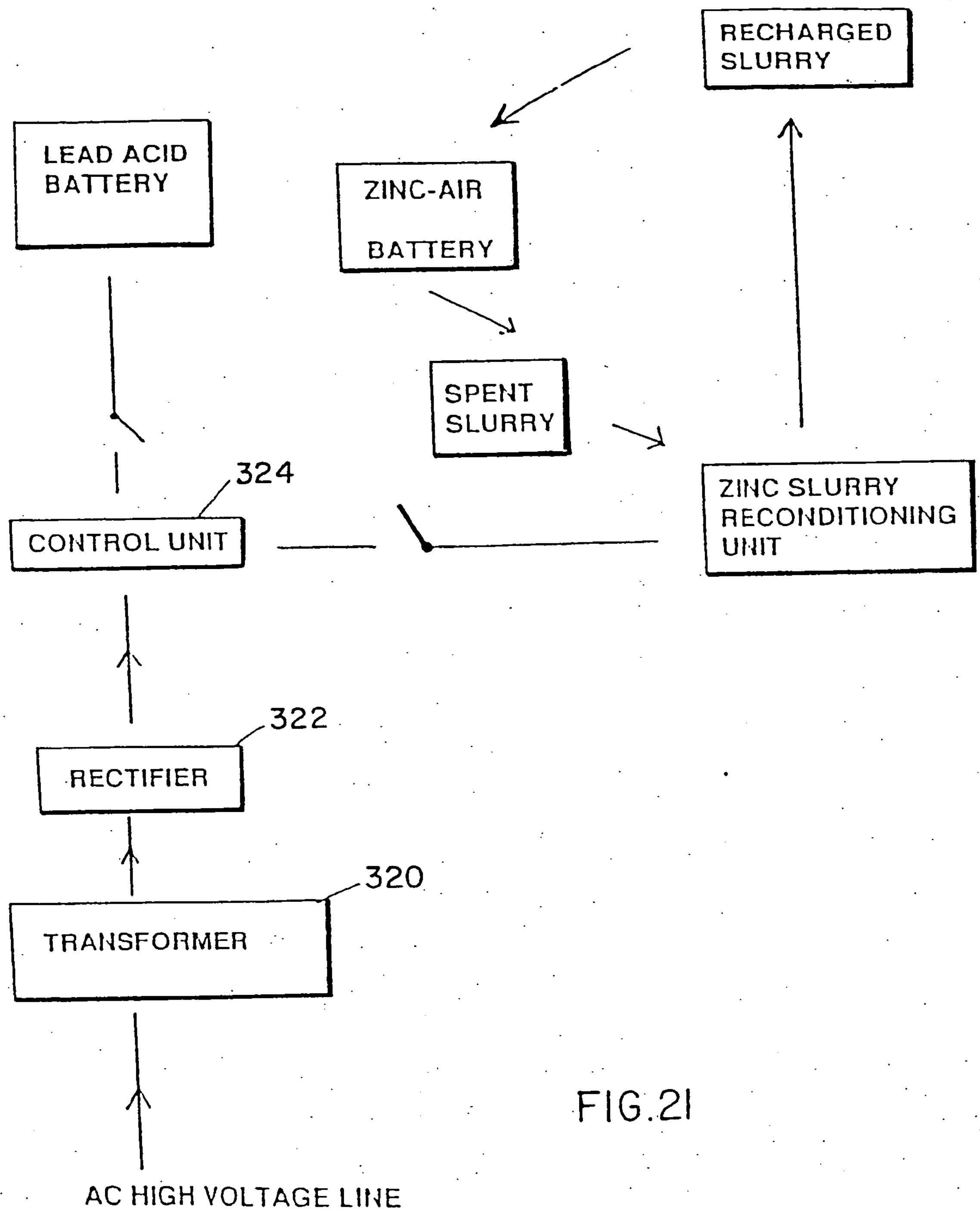
RECHARGED SLURRY
LEAD ACID BATTERY
ZINC-AIR BATTERY
SPENT SLURRY
324
CONTROL UNIT
ZINC SLURRY RECONDITIONING UNIT
322
RECTIFIER
320
TRANSFORMER
AC HIGH VOLTAGE LINE

FIG.21

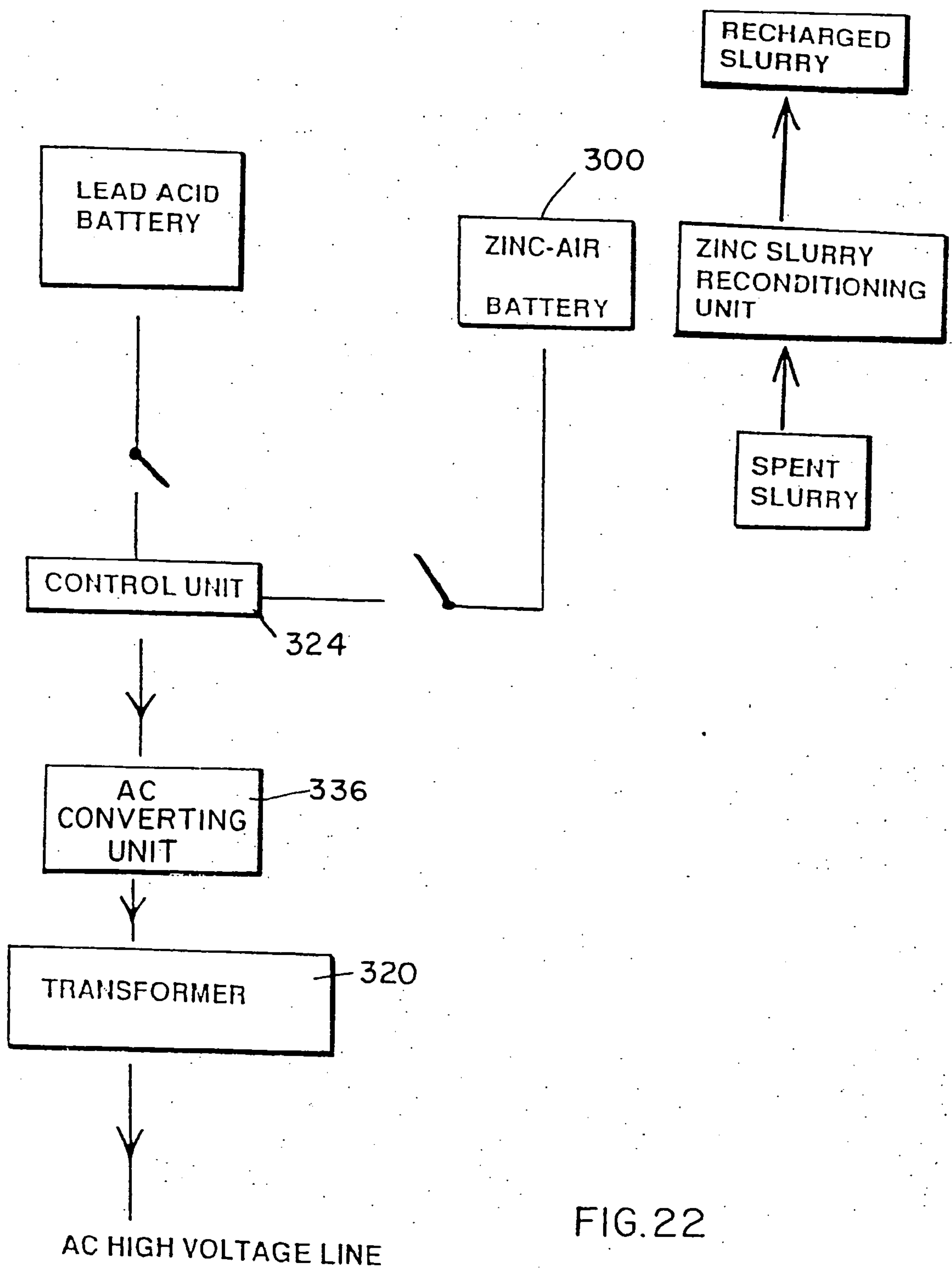
RECHARGED SLURRY
300
LEAD ACID BATTERY
ZINC-AIR BATTERY
ZINC SLURRY RECONDITIONING UNIT
SPENT SLURRY
CONTROL UNIT
324
AC CONVERTING UNIT
336
TRANSFORMER
320
AC HIGH VOLTAGE LINE

FIG. 22

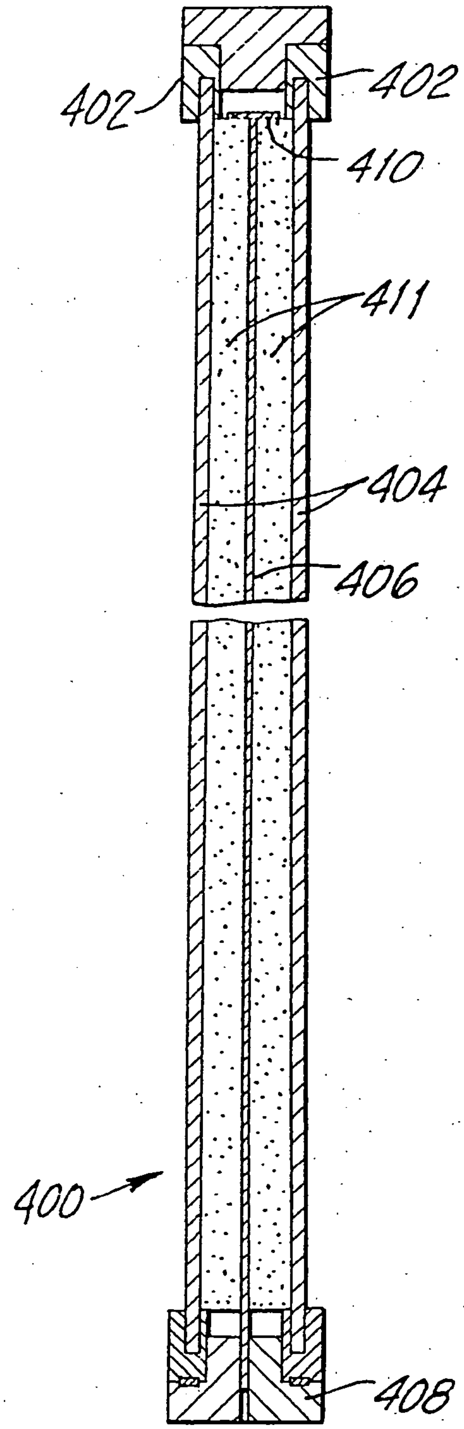

FIG.23

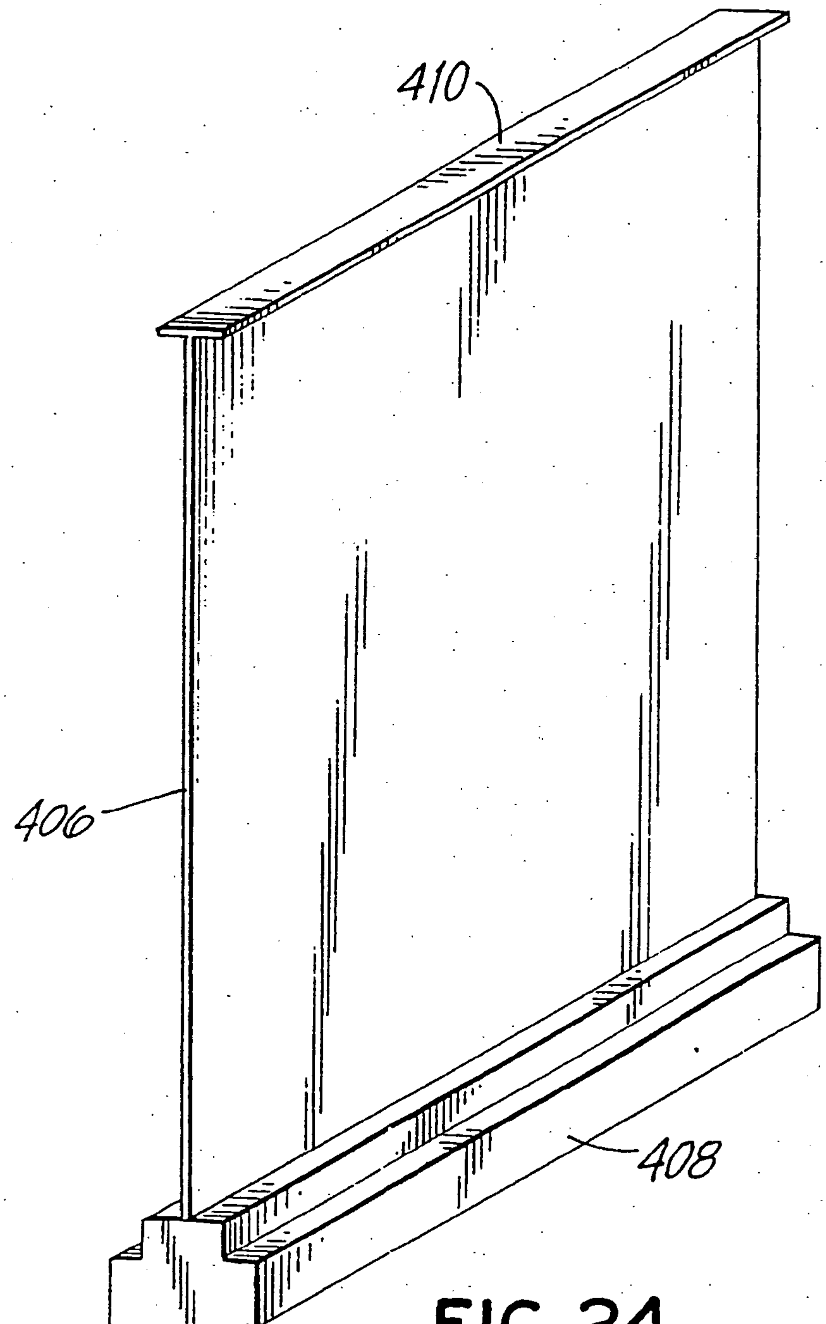

FIG.24

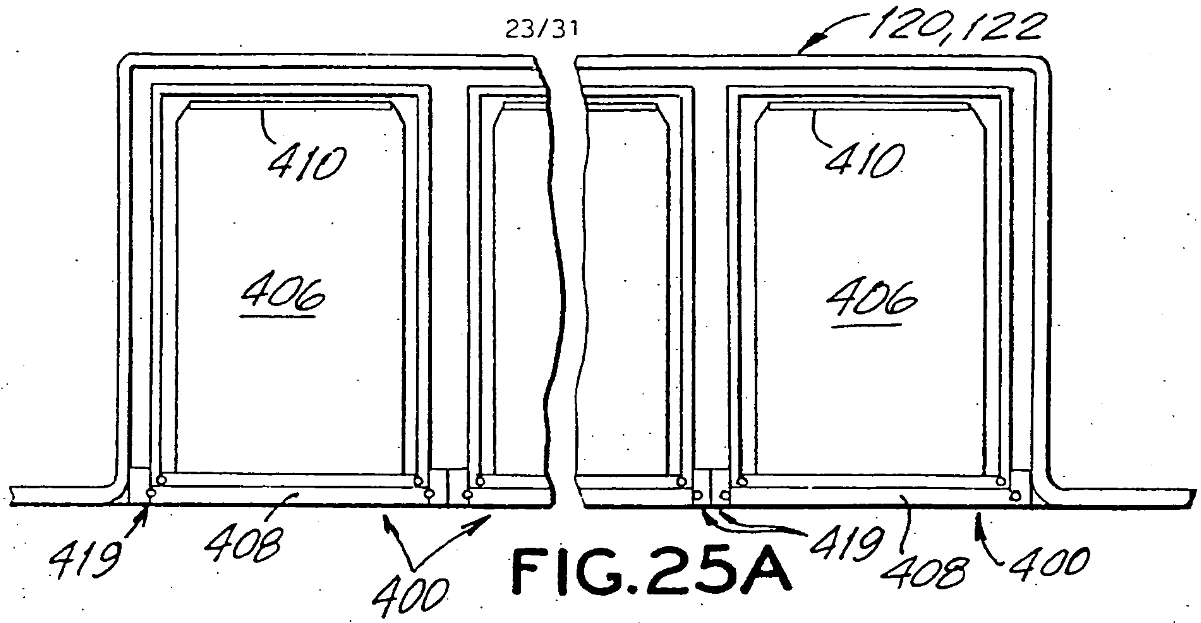

FIG.25A

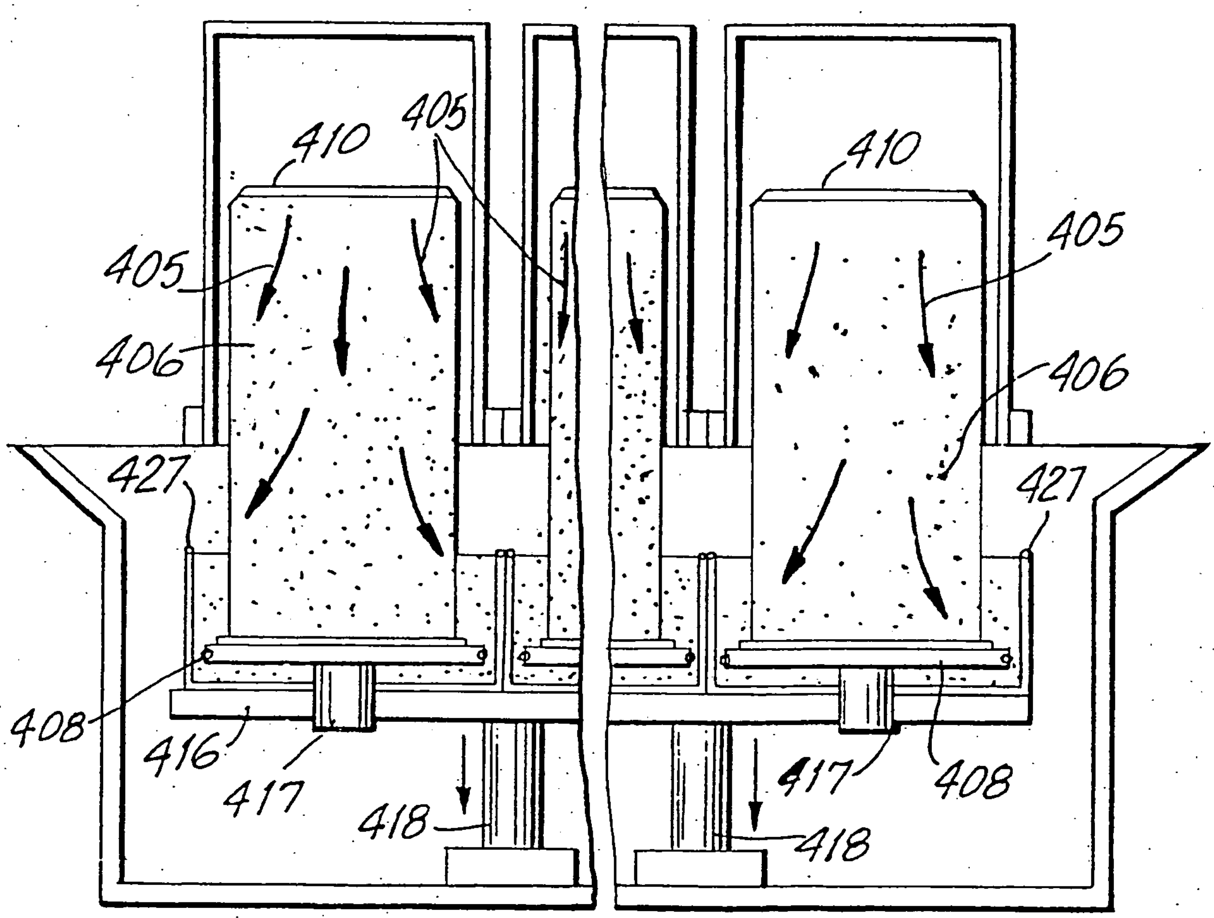

FIG.25B

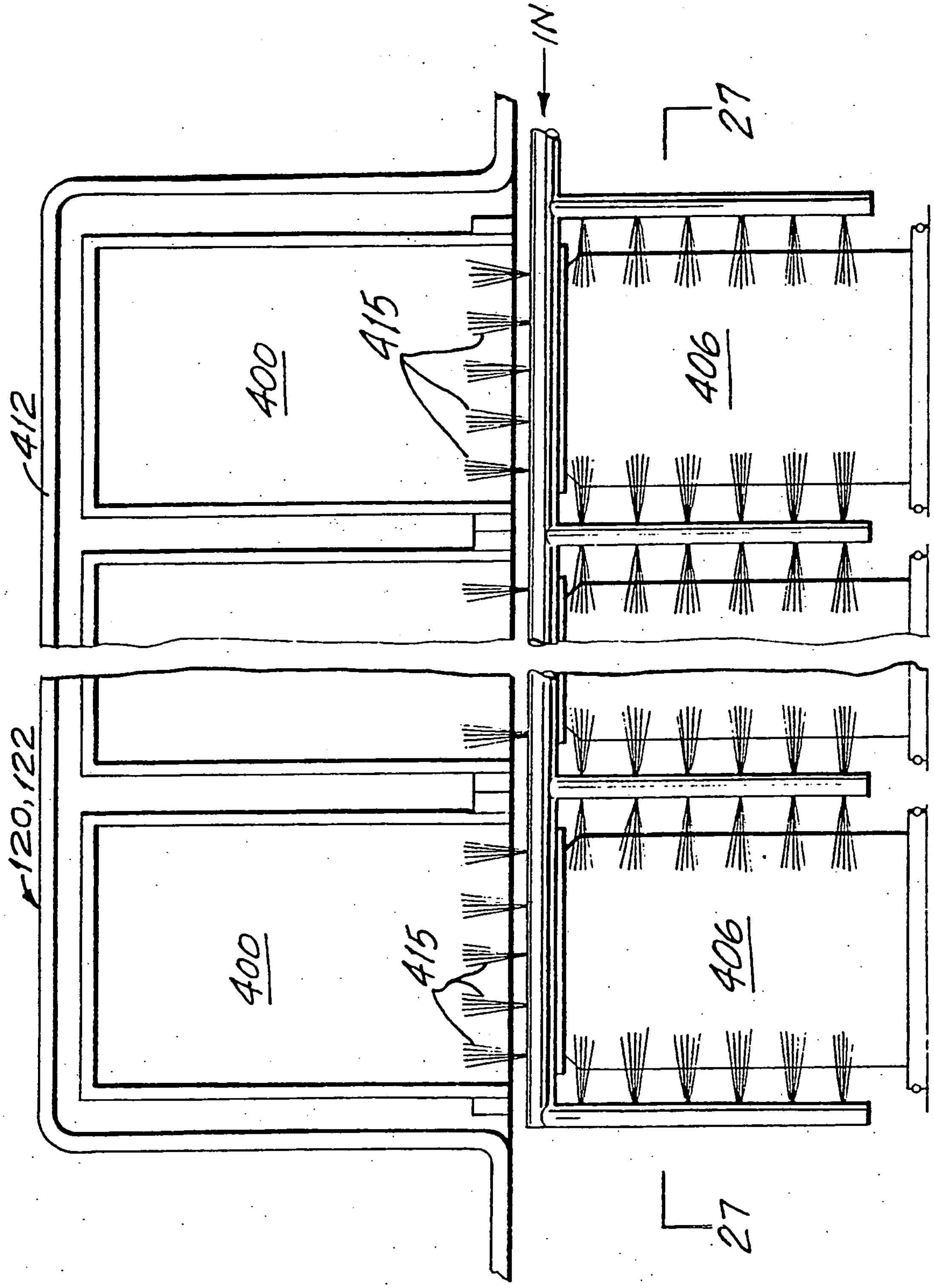

FIG.25C

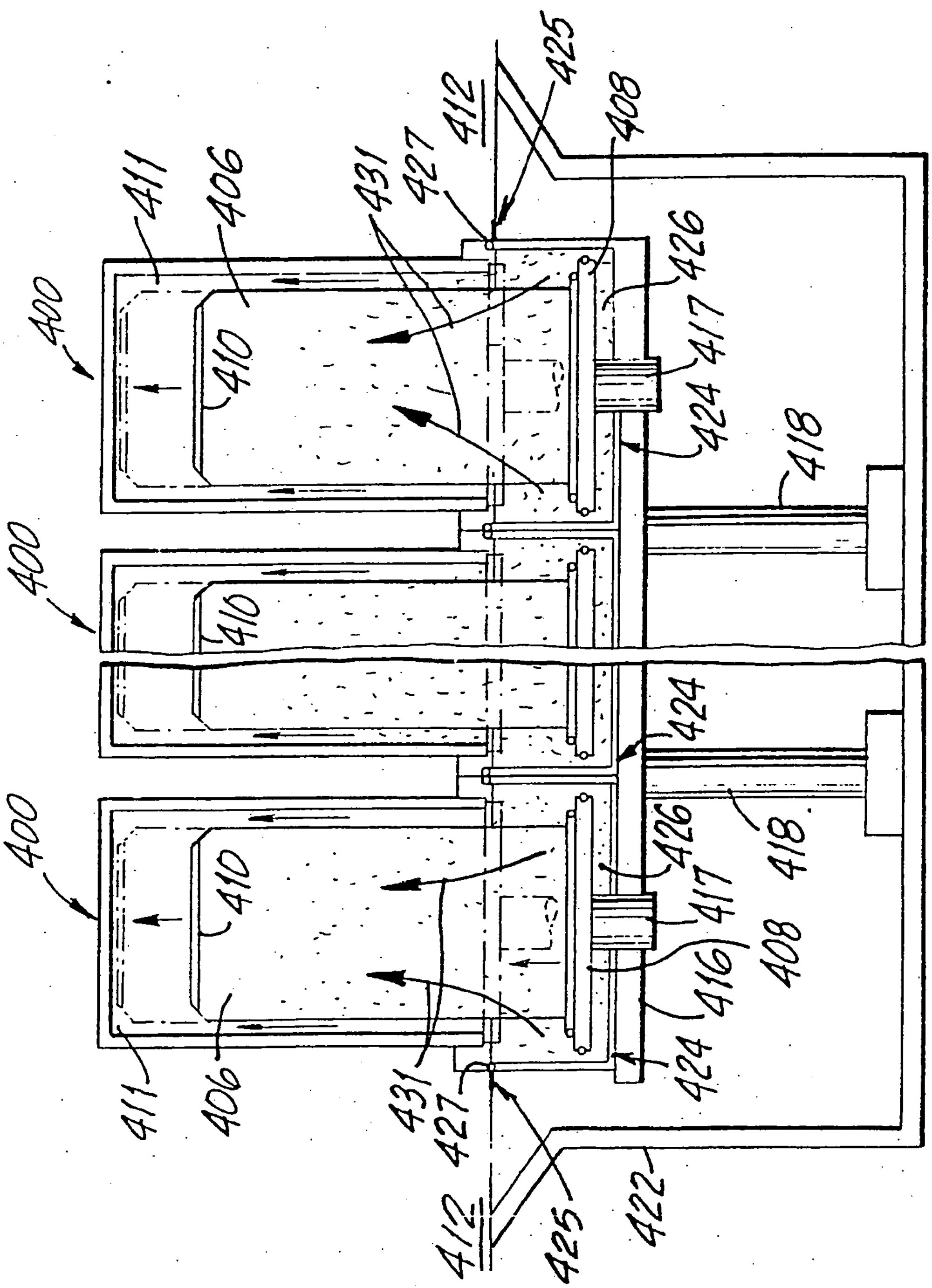

FIG.25D

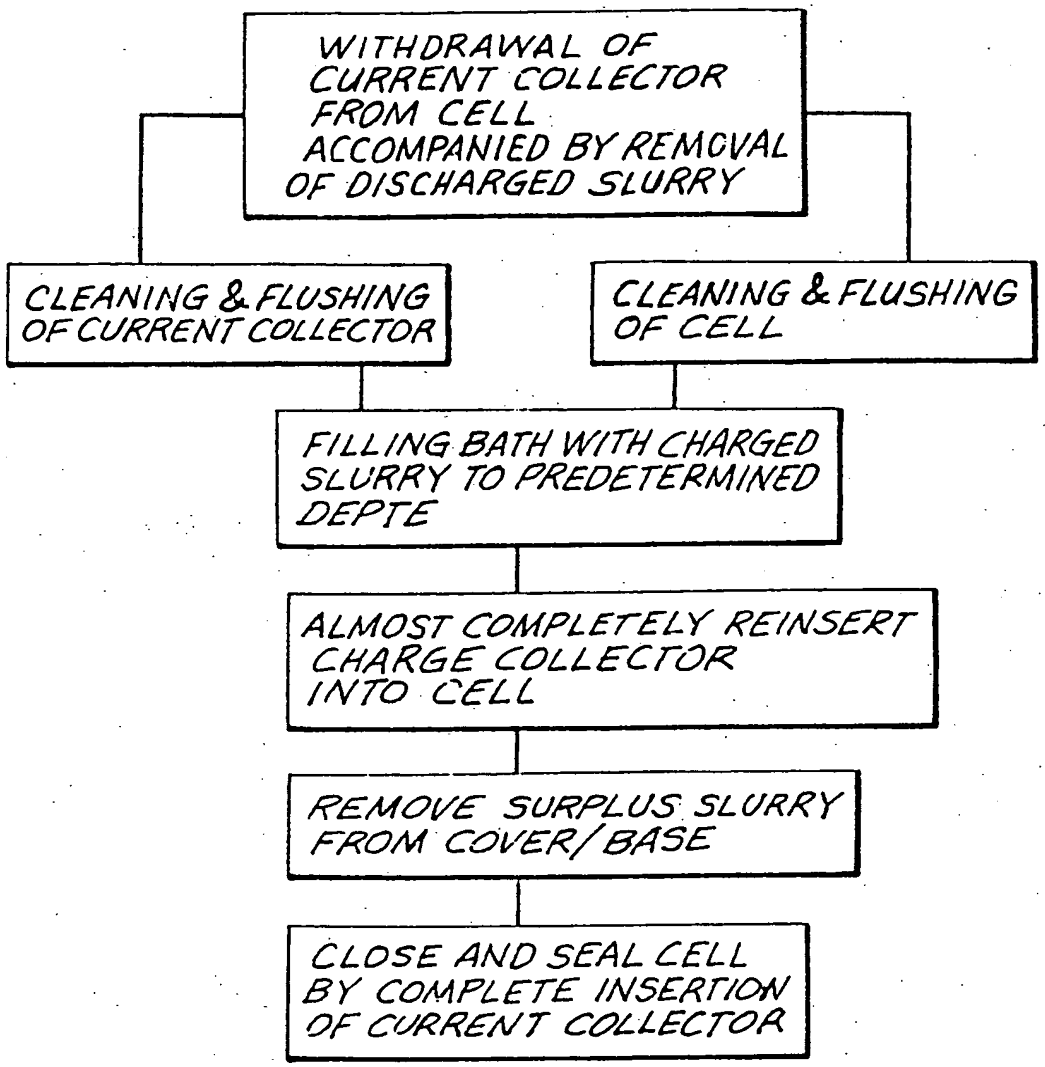
WITHDRAWAL OF CURRENT COLLECTOR FROM CELL ACCOMPANIED BY REMOVAL OF DISCHARGED SLURRY
CLEANING & FLUSHING OF CURRENT COLLECTOR
CLEANING & FLUSHING OF CELL
FILLING BATH WITH CHARGED SLURRY TO PREDETERMINED DEPTE
ALMOST COMPLETELY REINSERT CHARGE COLLECTOR INTO CELL
REMOVE SURPLUS SLURRY FROM COVER/BASE
CLOSE AND SEAL CELL BY COMPLETE INSERTION OF CURRENT COLLECTOR

FIG.26

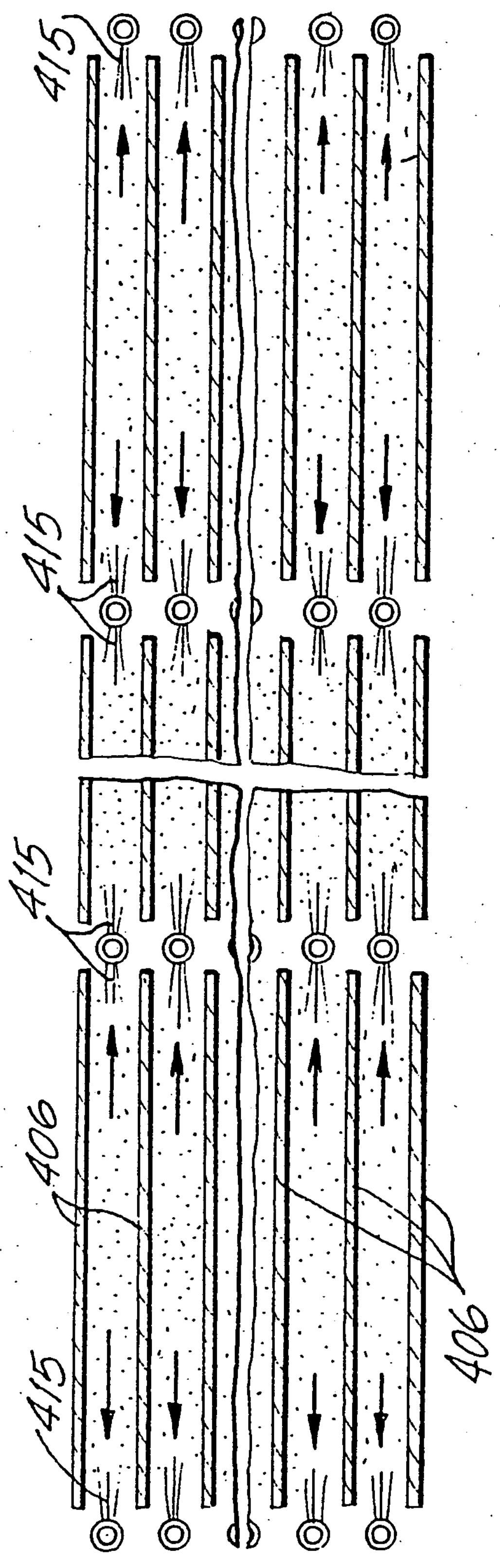

FIG.27

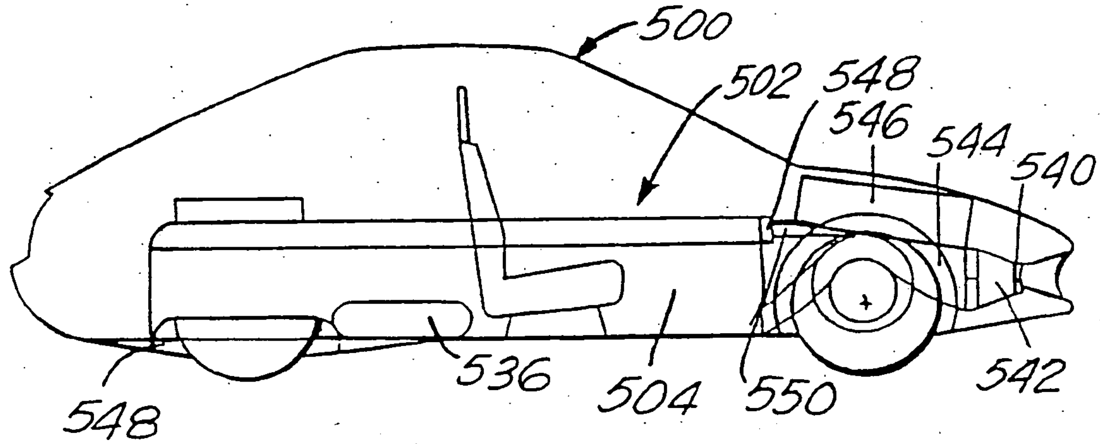

FIG.28A

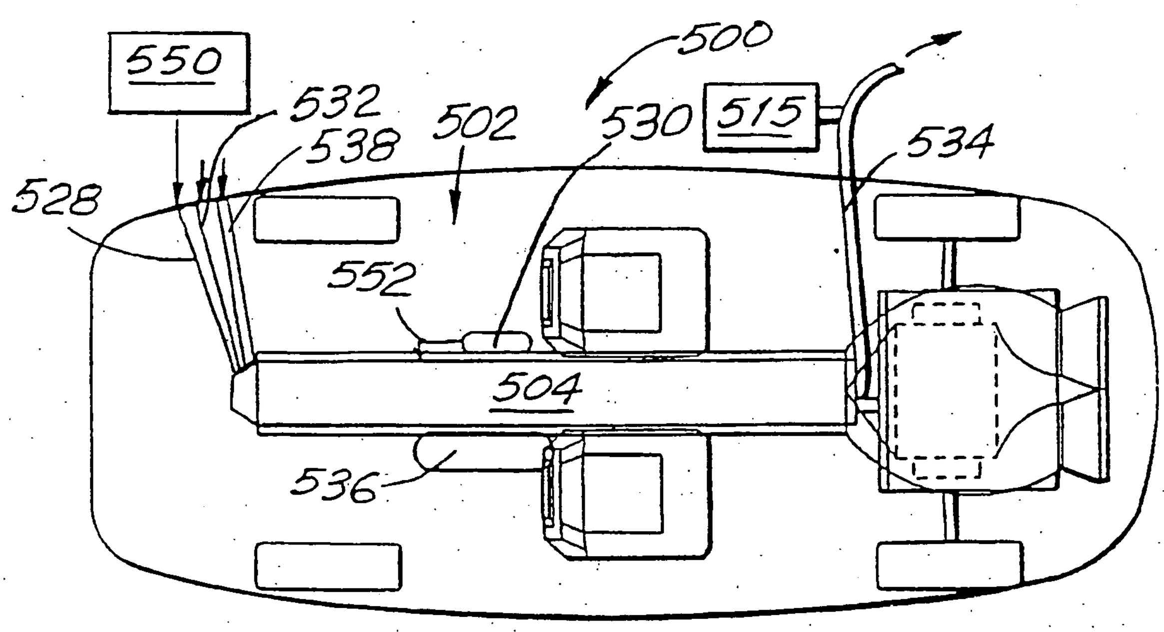

FIG.28B

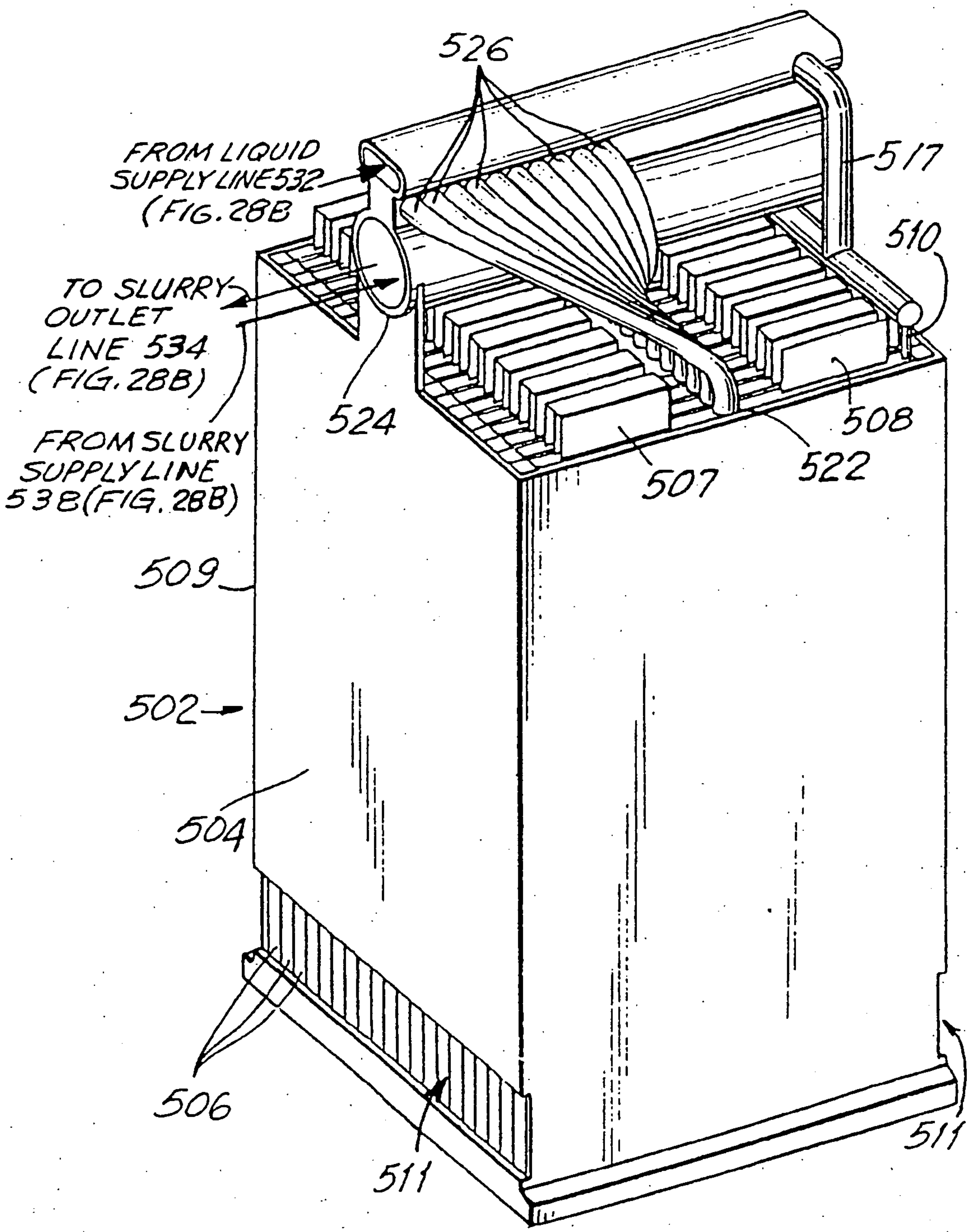
526
FROM LIQUID
SUPPLY LINE 532
(FIG. 28B
517
510
TO SLURRY
OUTLET
LINE 534
(FIG. 28B)
524
FROM SLURRY
SUPPLY LINE
538 (FIG. 28B)
508
522
507
509
502
504
506
511
511

FIG.29

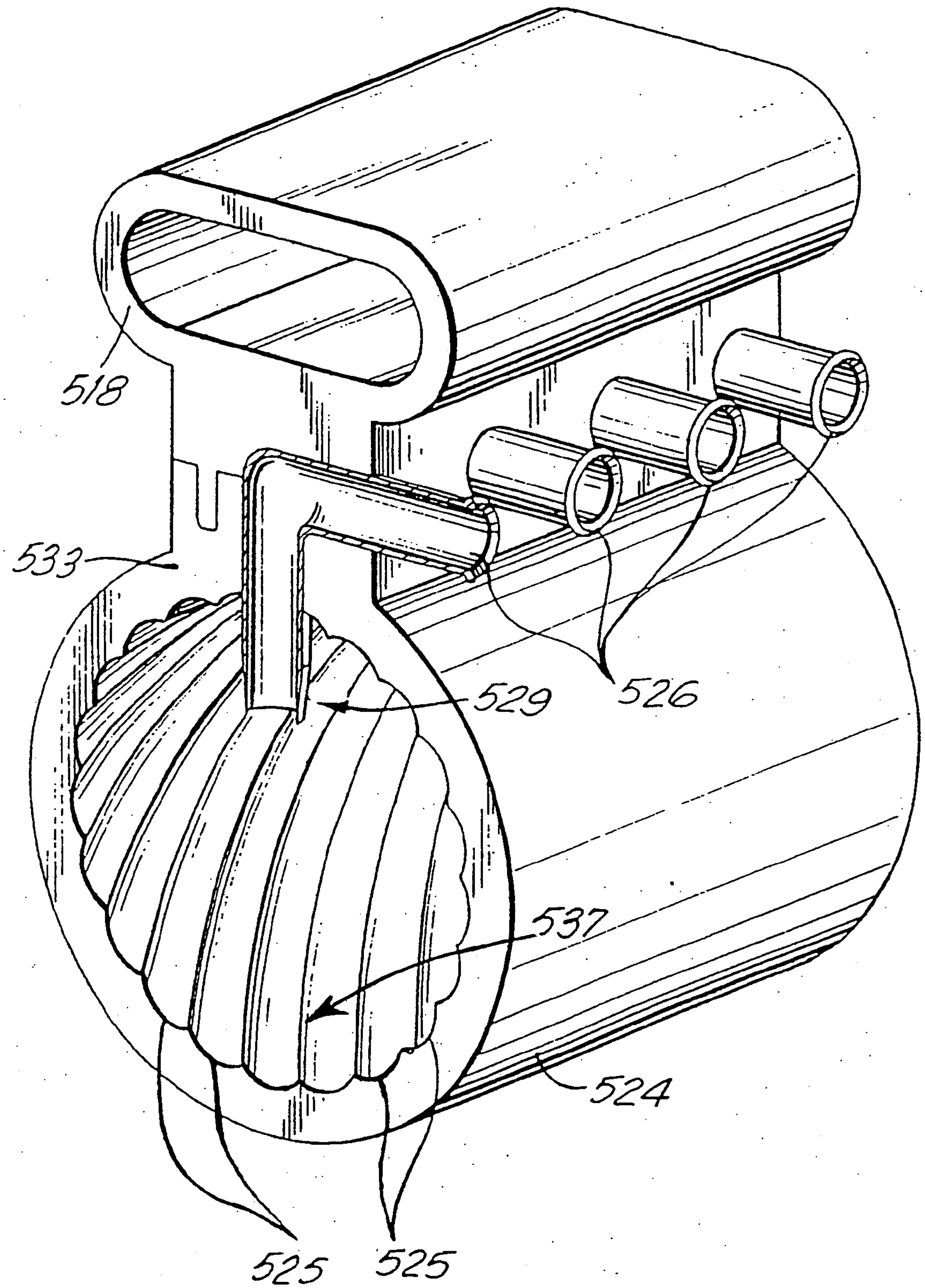

FIG. 30

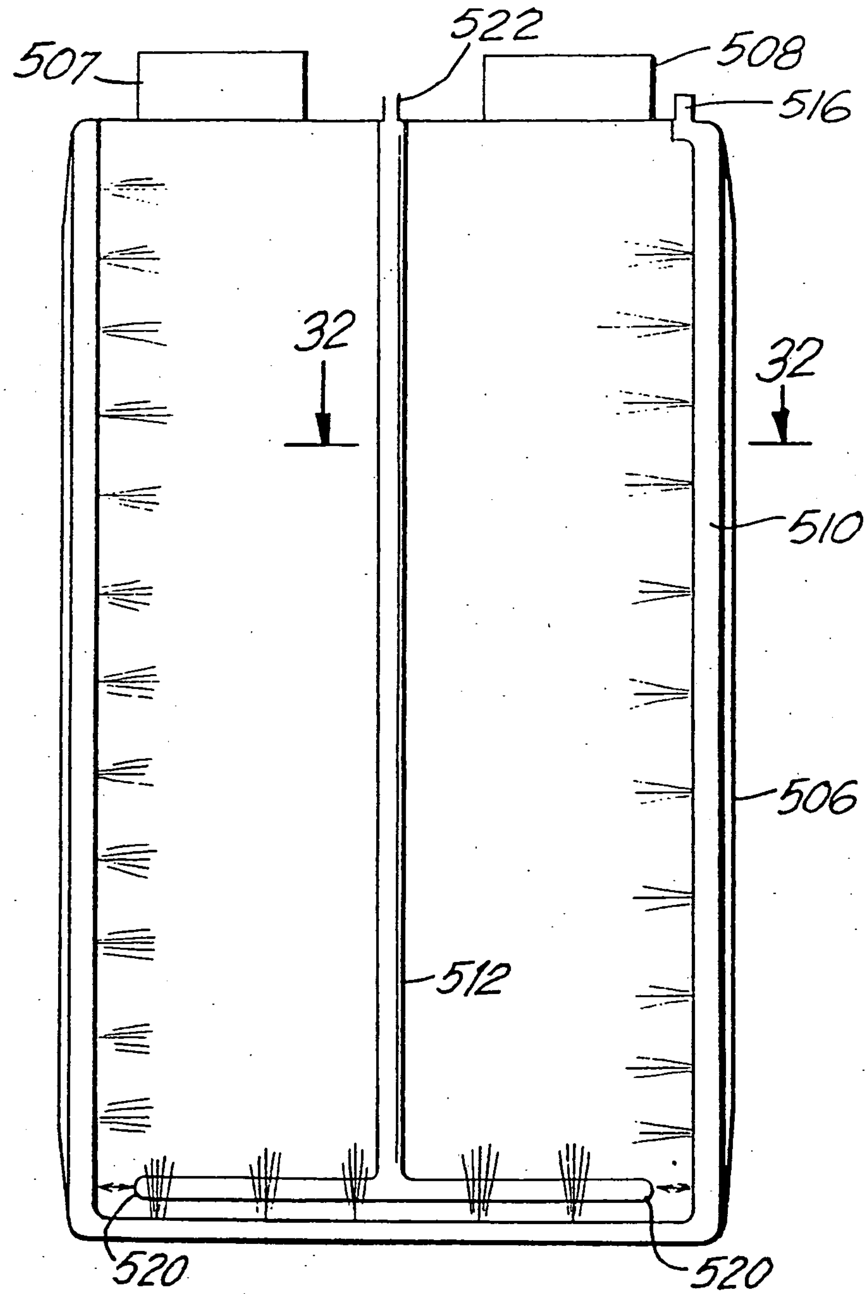

FIG.31

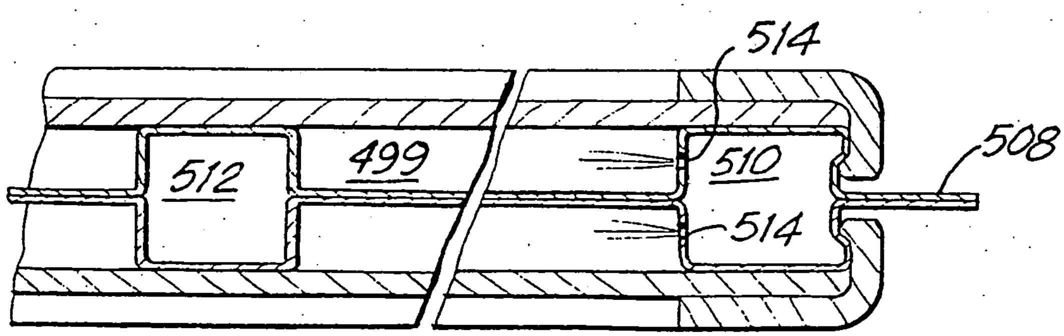

FIG.32

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/05712

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): H02J 7/00, H01M 8/00
U.S.Cl: 320/2, 429/27

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	320/2, 61 429/14,15,27

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US,A, 4,448,858 (GRAF et al) 15 MAY 1984 See entire disclosure	1-3,15-17, 50-57
Y		4-13,18-27 28-41,43-50
Y	US,A, 3,847,671 (LEPARULO et al) 12 NOVEMBER 1974 See entire disclosure	1-13,15-27 28-41,43-50
Y	US,A, 4,172,924 (WARSZAWSKI) 30 OCTOBER 1979 See entire disclosure	1-13,15-27 28-41,43-50
A	US,A, 4,081,693 (STONE) 28 MARCH 1978	1-13,15-27 28-41,43-50

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
05 DECEMBER 1991	20 DEC 1991
International Searching Authority	Signature of Authorized Officer